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TECHNICAL SUPPORT DOCUMENT: ENERGY EFFICIENCY STANDARDS FOR CONSUMER PRODUCTS:

ROOM AIR CONDITIONERS, WATER HEATERS, DIRECT HEATING
EQUIPMENT, MOBILE HOME FURNACES, KITCHEN RANGES AND OVENS,
WOL HEATERS, FLUORESCENT LAMP BALLASTS & TELEVISION SETS.

VOLUME 2: FLUORESCENT LAMP BALLASTS, TELEVISION SETS,
ROOM AIR CONDITIONERS, & KITCHEN RANGES AND OVENS

November 1993

U.S. Department of Energy
Assistant Secretary,
Energy Efficiency & Renewable Energy
Office of Codes and Standards

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Washington, DC 20585**

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Volume B

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CHAPTER 1. ENGINEERING ANALYSIS

1.1 INTRODUCTION

A fluorescent lamp ballast is an electrical device required for starting and operating fluorescent lamps. The ballast provides the high voltage needed to ignite the discharge (start the lamp) and then limits the current when the discharge is established. This is required because the lamp is initially an infinite impedance and becomes a virtual short circuit when the discharge is established. The starting and operating conditions of each type of fluorescent lamp are specified by the lamp manufacturers through the American National Standards Institute (ANSI), Electric Lamp Committee, C78.1, to assure that the life of the lamp and light output meet their ratings. The important specifications for lamp-life are the lamp current, the maximum starting voltage, the filament voltage, and the lamp current crest factor.¹

The characteristics of the fluorescent ballast are specified by an ANSI Fluorescent Ballast Committee, C82.1. They include operating voltage, ballast factor, and power factor. Other characteristics of concern addressed by standards groups include electromagnetic interference (EMI) and harmonic content. The only important parameters not specified by ANSI are ballast efficiency and system (lamp-ballast) efficacy. Total harmonic distortion (THD) of magnetic ballasts is usually between 15 and 25% of the line current (1). For electronic ballasts, THD is typically below 30%. For compact fluorescent lamps, THD can be higher. Presently, there is no standard for harmonic content of ballasts output; the proposed ANSI standard for electronic high-frequency ballasts is expected to have a limit on harmonics.

The standard fluorescent lamp ballast (magnetic core-coil) is manufactured with discrete electrical components. The main elements of the ballast are the magnetic choke that limits the current, a step-up transformer to obtain the high starting voltage, and two capacitors, one corrects for the low trailing power factor and the other changes the phase voltage between the two lamps (when a single ballast operates two lamps). Rapid-start ballasts have independent secondary windings for applying a voltage to the filaments. Instant-start lamps do not apply voltage across filaments and rely upon high voltage to initiate the discharge. Standard ballasts operate at an input frequency of 60 Hz and operate the lamp(s) at the same 60 Hz frequency.

The electronic high-frequency ballast uses the same 60 Hz input power, but it operates the lamps at a frequency generally above 20 kHz. This ballast provides the same function as the standard ballast. The electronic ballast is more efficient than the standard core-coil magnetic ballast in transforming the input power to lamp requirements. In addition, the fluorescent lamp is more efficacious when operated at high frequencies (20,000 or above). These two improvements result in a 20 to 25% increase in efficacy for the lamp-ballast system. At present,

¹ The lamp current crest factor is defined as the peak current divided by the root mean square current.

there are no ANSI standards for the electronic ballast. However, characteristics specified for the magnetic fluorescent lamp ballast are expected to be similar for electronic ballasts.

The manufacturing procedures for the electronic ballast are the same as employed for most electronic equipment using discrete and integrated semiconductor components. Chokes and transformers are still used along with circuit boards to electrically connect the discrete devices. Manufacturers use ferrite cores for the high-frequency output circuits. Since the electronic ballasts are packaged in the same size "cans" as magnetic core-coiled ballasts, they can be secured in fixtures designed to be used with core-coil ballasts. Electronic ballasts have an installation advantage because of their lighter weight.

There is now an ANSI C.82.2 standard test procedure for evaluating the performance of a ballast (2). The parameters measured include filament voltage, lamp current crest factor, power factor, lamp current, ballast factor, and starting voltage. The measurements are made in a draft-free thermal environment of 25 °C. The lamp is measured in an open strip-line type fixture such that the minimum lamp wall temperature is between 37 and 40 °C.

Another parameter has been added to the regulations in the National Appliance Energy Conservation Act (NAECA), ballast efficacy factor (BEF), to assess the performance of a ballast.

$$\text{BEF} = \text{Ballast Factor} / \text{Input Power(W)}$$

The BEF is defined as the ballast factor divided by the input power to the ballast. The ballast factor is the ratio of the test lamp light output with the ballast under test to the light output of the same lamp measured against the reference ballast. Although the test procedure for ballasts does not specifically mention electronic ballasts, they can be tested in the same manner as magnetic ballasts, as has been done to show compliance with previous state and the present federal standards.

The F40 and the F96 fluorescent lamp ballasts are the only ones presently regulated. These ballasts comprise about 80% of the market. The minimum BEFs for the existing NAECA standards are listed in Table 1.1. These efficiency factors apply to all ballasts manufactured after January 1, 1990, and sold by manufacturers after April 1, 1990. The standards apply to ballasts operating at input voltages of both 120 and 277V with an input current frequency of 60 Hz. For two 40W F40T12 lamps, the BEFs are 1.06 and 1.05 for 120V and 277V, respectively. Although the regulated ballasts can operate the energy-savings lamps, all BEF tests are made with 40W F40T12, 75W F96T12, or 110W F96T12HO lamps.² The standards do not apply to dimming ballasts, ballasts designed for use in ambient temperatures of 0 °F or less, or ballasts that have a power factor less than 0.90 and are designed for use in residential building applications.

² An energy-saving lamp is a reduced wattage (34 W) krypton-filled lamp.

Table 1.1 Minimum Allowable Ballast Efficacy Factors

Ballast-Lamp System	Nominal Lamp Watts	Ballast Efficacy Factor
1 F40T12	40	1.805
2 F40T12	80	1.06/1.05
2 F96T12	150	0.570
2 F96T12HO	220	0.390

The efficacy of the lamp ballast system is defined in terms of lumens-per-watt (lm/W). The term *efficacy* is standard nomenclature for efficiency when the input and output have different dimensions. Efficacy is measured after a lamp has been operated for 100 hours, and is described as the initial characteristic. The light output is also specified at 40% of lamp-life to assess the lumen depreciation of the lamp. While there are no tests specified for the electronic ballast-lamp system, the same procedure is used to measure their efficacy. The same instruments and set-up can be used for the high-frequency system since only the 60 Hz input power and the light output are measured.

1.2 PRODUCT CLASSES

The ballast product classes are based upon the number of lamps and lamp type (power, length). The types currently regulated (F40 and F96 ballasts) are listed below:

1. One-lamp F40 ballast (120, 277V), to operate one 40W F40 rapid-start T12 fluorescent lamp;
2. Two-lamp F40 ballast (120, 277V), to operate two 40W F40 rapid-start T12 fluorescent lamps;
3. Two-lamp F96 ballast (120, 277V), to operate two 75W F96 instant-start T12 fluorescent lamps; and
4. Two-lamp F96HO-ballast (120, 277V), to operate two 110W F96 high-output rapid-start T12 fluorescent lamps.

Other important product classes that may impact the market in the near future are the three- and four-lamp F40 ballasts and the four-foot T8 lamp ballast system. The 32W F32T8 lamp-ballast system is more efficient than the T12 fluorescent system. The T10 lamps are designed to operate with the 40W F40T12 ballast, so they do not need a separate product class. Six additional product classes considered in this rulemaking are the following:

1. Three- and four-lamp ballasts (120, 277V), to operate three and four 40W F40 rapid-start T12 fluorescent lamps;
2. One-, two-, three-, and four-lamp ballasts (120, 277V), to operate one, two, three and four 32W F32T8 fluorescent lamps.

There are electronic ballasts designed to operate three and four fluorescent lamps. Most fluorescent fixtures are four-lamp types with the three-lamp types growing rapidly. With magnetic ballasts, three-lamp fixtures generally use a two-lamp and a one-lamp ballast, or, if possible, the lamps are tandem-wired so that two-lamp ballasts can be employed throughout the lighting layout. Four-lamp fixtures use two-lamp ballasts per fixture. There are no three- or four-lamp magnetic ballasts being manufactured at present.

Compact fluorescent ballasts have not been included as a separate product class in this analysis. For integral lamp-ballast systems, which is the case for compact fluorescents, a non-destructive test to conduct the measurement of ballast factor is not possible.

Dimming ballasts, which provide the ability to vary light output, have been set aside as a separate product class. However, a separate cost-efficiency analysis is not performed because any standards developed for non-dimming ballasts can also apply to dimming ballasts operated at full-light output. Table 1.2 lists the product classes analyzed.

Table 1.2 Product Classes for Fluorescent Lamp Ballasts

1 F40T12
2 F40T12
2 F96T12
2 F96T12HO
3 F40T12
4 F40T12
1 F32T8
2 F32T8
3 F32T8
4 F32T8

1.3 DESIGN OPTIONS

Table 1.3 lists possible design options for improving the efficacy of the energy-efficient magnetic lamp ballast. The basic options are the electronic high-frequency ballast and the cathode cut-out ballast. The dimmable/two-level electronic high-frequency ballast also has the potential to save significant amounts of energy.

Table 1.3 Design Options For Fluorescent Lamp Ballasts

Cathode Cutout
Electronic High-Frequency
Dimmable Two-Level

Energy-Efficient Magnetic Ballast (Baseline)

The energy-efficient (EE) magnetic ballast is one that just meets the minimum allowable BEFs found in Table 1.1. This ballast fundamentally uses the same circuit design as the standard ballast. The EE magnetic ballast employs better materials to increase the system efficacy by 9 or 10%. Copper wire is used in place of aluminum wire, which decreases the ballast's I^2R losses. Higher grade magnetic materials are used for the choke and transformer, decreasing their I^2R losses. The ballast efficiency in transforming the input power to the lamp increases from 80% to about 87%. The system efficacy for two, 40W F40T12 cool white lamps is about 67 lm/W. The use of copper wire instead of aluminum wire increases the weight of the ballast. The EE magnetic ballast could be made even more efficient, but this would result in a further increase in the package size and weight.

Cathode Cut-out Ballasts

The cathode cut-out ballast is a modification of the EE magnetic ballast; it uses an electronic circuit to remove the filament power after the discharge has been initiated for rapid-start lamps. These ballasts start the lamps in the normal manner with a suitable filament power. Operating lamps without filament power maintains the light output while reducing power by about two watts per lamp. The efficacy for the two-lamp system is 69 lm/W. At 60 Hz operation there is some loss of lamp-life (0-25%). This approach is effective for dedicated lighting systems where the lamps are operated at full-light output. There will be a significant loss in lamp-life if filament power removal is used with fluorescent dimming systems. The cathode cut-out technique is generally used with magnetic ballasts. Some electronic ballast designs reduce the cathode voltage during operation, but do not reduce it to zero.

Electronic High-Frequency Ballasts

This ballast operates the lamp at a high frequency for an increased lamp efficacy of 10 to 20% compared to 60 Hz operation. The electronic ballast is also about 10 -15% more efficient than the standard ballast in conditioning the input power for a total system efficacy increase of 20 to 25%. The typical efficacy for two 40W F40T12 cool white lamps is about 78 lm/W. The front end of the electronic ballast is a full-wave rectifier circuit that converts the 60 Hz AC power into DC power. It is filtered to reduce the modulation. This DC voltage is the input to an oscillating circuit that converts the DC power to a high frequency of 20 kHz or more. The anode fall of the lamp is decreased by about ten volts at the high frequency which results in a 10 to 15% increase in the lamp's efficacy. The ballasting action (current-limiting) is done at high frequency with smaller components, reducing ballast losses and making the ballast more efficient. It is becoming common practice to substitute integrated circuits for discrete components, saving an additional 1.5 - 2.0 W. The high-frequency operation reduces the 60-cycle flicker associated with fluorescent lamps operated with magnetic ballasts. This may reduce the occurrence of headaches and eyestrain sometimes associated with fluorescent lighting.

Electronic ballasts can operate a rapid- or instant-start lamp. A rapid-start lamp requires a filament voltage to keep the lamp ready for rapid starting. In an instant-start lamp, a higher starting voltage initiates the discharge and allows for the omission of the filament voltage. This measure saves about 2 watts per lamp during operation of the lamps. For most presently used T12 lamps, instant start is not viable; the filament would have to be redesigned. There is at least one T12 lamp that can operate as an instant-start lamp; however, its lifetime is less than half of a standard T12 lamp.

Dimming Two-Level Ballasts

Two-level electronic high-frequency ballasts are now available that can alter the light output of fluorescent lamps by 50%. More sophisticated ballasts can continuously lower the light output to 1% of full light output. These ballasts have a circuit that changes the output current (lamp's light output) via a low voltage input signal. The important aspect of this design is that full-filament power is maintained at the low-light output levels. Maintaining filament power is very important in preserving lamp-life when lamp current is reduced. There are auxiliary control systems that can be used to dim standard lamp-ballast systems. These control systems condition input power to the ballasts so that the filament power is reduced at lower light output. The filament power reduction can limit the dimming range to about 50% of full light output with no loss of lamp-life. In the dimmed mode, the lamp-ballast system will generally have a slight decrease in efficacy. However, there is a significant energy savings because of reduced input power. Dimming ballasts cost more because of additional auxiliary command equipment. This type of ballast has been excluded from the existing ballast regulations.

1.4 ENERGY USE DATA

Table 1.4 lists the average system power (lamps and ballast) for several types of magnetic and electronic high-frequency ballasts operating the F40, F96, and the newer F32T8 type fluorescent lamps. All the values are measured with the lamps at their optimum lamp-wall temperature (~40 °C) in an open-air fixture. Data were obtained from laboratory measurement (3),(4). There are no three- or four-lamp magnetic ballasts, hence no power values for those configurations are found in the table. In the cost/efficiency tables for three- and four-lamp fixtures, a single- and two-lamp magnetic ballast and two, two-lamp magnetic ballasts were used, respectively. In order to calculate fluorescent ballast energy consumption, lamp usage was estimated to be 3,642 hours per year.³

Table 1.4 System Power (W) For Magnetic and Electronic Ballasts

Lamp	EE Magnetic	Electronic, Rapid Start
1 F40	47	38
2 F40	87	74
3 F40	NA	109
4 F40	NA	124
2 F96	158	132
2 F96HO	237	190
1 F32T8	37	32
2 F32T8	74	64
3 F32T8	NA	95
4 F32T8	NA	132

1.5 COST-EFFICIENCY DATA

In this section, estimates of manufacturer cost data for increasing the efficiency of EE magnetic ballasts are presented. Data for two-lamp F40 ballasts have been obtained from testimony at a trial and from experts in the field, including a ballast manufacturer (5). For other product classes, extrapolation and retail prices were used to generate manufacturer costs. For the cost-benefit analysis, an EE magnetic core-coil ballast was chosen as the baseline model in each product class. This type of magnetic ballast is required to meet the NAECA standard. The BEFs are calculated by assuming a relative light output of 95% for all ballasts and by using the power values in Table 1.4. EE magnetic ballasts with cathode cutout are shown as an option for the

³We arrived at this figure from our analysis of data from the *Nonresidential Buildings Energy Consumption Survey: Commercial Buildings, Consumption and Expenditures 1983*; September 1986, DOE/EIA-0318(83).

F40 and F32 lamps. The F96 lamps require cathodes that are continuously powered; therefore, cathode cutout is not a viable option for these lamps. For lamps that undergo cathode cutout, their lifetime is reduced by about 25% relative to lamps without cathode cutout. This reduced lifetime is accounted for in the life-cycle cost analyses. The manufacturer cost differential for this type of ballast is estimated to be \$2.00. The cost differential between EE magnetic and electronic ballasts is approximately \$9.00 for most product classes, with the exception of the two-lamp F96HO system. Lifetimes for magnetic and electronic ballasts have been assumed equal at 15 years. Most of the incremental manufacturer cost is for purchased parts and materials (see Appendix A of this volume for details).

1.6 MAXIMUM TECHNOLOGICALLY FEASIBLE DESIGNS

For all product classes, the maximum technologically feasible BEFs can be achieved with electronic ballasts. The last entry in each table below shows the maximum technologically feasible BEF; it results from the use of solid-state electronics in fluorescent ballasts. For example, for a two-lamp F40 ballast, the maximum technologically feasible BEF is 1.28.

All of the energy use and manufacturer cost values in the tables below have an uncertainty associated with them. For the maximum technologically feasible design, the 95% confidence interval for BEF is estimated to range from the BEF value given in the table to a 10% higher value. For example, for a two-lamp F40 ballast, the BEF interval ranges from 1.28 to 1.41. The lower BEF value is retained because the estimates in the tables are considered definitely achievable.

Table 1.5 Cost-Efficiency Data for Fluorescent Ballasts (1-Lamp F40)

Standard Level Number	Ballast Type (Design Option)	BEF	Power (W)	Energy Use (kWh/yr)	Manufacturer Cost 1991\$
	EE Magnetic	2.02	47	171.2	4.50
1	EE Magnetic + Cutout	2.11	45	163.9	6.50
2	Electronic, Rapid-Start	2.50	38	138.4	12.00

Table 1.6 Cost/Efficiency Data for Fluorescent Ballasts (2-Lamp F40)

Standard Level Number	Ballast Type (Design Option)	BEF	Power (W)	Energy Use (kWh/yr)	Manufacturer Cost 1991\$
	EE Magnetic	1.09	87	316.9	5.00
1	EE Magnetic + Cutout	1.15	83	302.3	7.00
2	Electronic, Rapid-Start	1.28	74	269.5	12.00

Table 1.7 Cost/Efficiency Data for Fluorescent Ballasts (2-Lamp F96)

Standard Level Number	Ballast Type (Design Option)	BEF	Power (W)	Energy Use (kWh/yr)	Manufacturer Cost 1991\$
1	EE Magnetic	0.60	158	575.4	8.40
	Electronic, Rapid-Start	0.72	132	480.7	15.00

Table 1.8 Cost/Efficiency Data for Fluorescent Ballasts (2-Lamp F96HO)

Standard Level Number	Ballast Type (Design Option)	BEF	Power (W)	Energy Use (kWh/yr)	Manufacturer Cost 1991\$
1	EE Magnetic	0.40	237	863.2	15.50
	Electronic, Rapid-Start	0.50	190	692.0	18.60

Table 1.9 Cost/Efficiency Data for Fluorescent Ballasts (3-Lamp F40)

Standard Level Number	Ballast Type (Design Option)	BEF	Power (W)	Energy Use (kWh/yr)	Manufacturer Cost 1991\$
1	EE Magnetic	0.71	134	488.0	9.50
	EE Magnetic + Cutout	0.74	128	466.2	13.50
	Electronic, Rapid-Start	0.87	109	397.0	18.00

Table 1.10 Cost/Efficiency Data for Fluorescent Ballasts (4-Lamp F40)

Standard Level Number	Ballast Type (Design Option)	BEF	Power (W)	Energy Use (kWh/yr)	Manufacturer Cost 1991\$
1	EE Magnetic	0.55	174	633.7	10.00
	EE Magnetic + Cutout	0.57	166	604.6	14.00
	Electronic, Rapid-Start	0.67	141	513.5	19.00

Table 1.11 Cost/Efficiency Data for Fluorescent Ballasts (1-Lamp F32T8)

Standard Level Number	Ballast Type (Design Option)	BEF	Power (W)	Energy Use (kWh/yr)	Manufacturer Cost 1991\$
	EE Magnetic	2.57	37	134.8	4.50
1	EE Magnetic + Cutout	2.71	35	127.5	6.50
2	Electronic, Rapid-Start	2.97	32	116.5	12.00
3	Electronic, Instant-Start	3.17	30	109.3	12.00

Table 1.12 Cost/Efficiency Data for Fluorescent Ballasts (2-Lamp F32T8)

Standard Level Number	Ballast Type (Design Option)	BEF	Power (W)	Energy Use (kWh/yr)	Manufacturer Cost 1991\$
	EE Magnetic	1.28	74	269.5	5.00
1	Magnetic + Cut-out	1.36	70	254.9	7.00
2	Electronic, Rapid-Start	1.48	64	233.1	12.00
3	Electronic, Instant-Start	1.58	60	218.5	12.00

Table 1.13 Cost/Efficiency Data for Fluorescent Ballasts (3-Lamp F32T8)

Standard Level Number	Ballast Type (Design Option)	BEF	Power (W)	Energy Use (kWh/yr)	Manufacturer Cost 1991\$
	EE Magnetic	0.85	111	404.3	9.50
1	EE Magnetic + Cutout	0.90	105	382.4	13.50
2	Electronic, Rapid-Start	1.00	95	346.0	19.00
3	Electronic, Instant-Start	1.06	89	324.1	19.00

Table 1.14 Cost/Efficiency Data for Fluorescent Ballasts (4-Lamp F32T8)

Standard Level Number	Ballast Type (Design Option)	BEF	Power (W)	Energy Use (kWh/yr)	Manufacturer Cost 1991\$
	EE Magnetic	0.64	148	539.0	10.00
1	EE Magnetic + Cutout	0.68	140	509.9	14.00
2	Electronic, Rapid-Start	0.72	132	480.7	21.00
3	Electronic, Instant-Start	0.76	124	451.6	21.00

CHAPTER 2. BASE CASE FORECASTS: COMMERCIAL LIGHTING

Several baselines were created to project national energy consumption without new ballast standards. Future prices of efficient technologies, partly dependent upon the extent to which current electric utility company programs promoting them will continue, are difficult to predict. Electric utility programs could permanently change the set of available technologies, as suppliers phase out older, less efficient (unsubsidized) designs. As newer technologies increase market share, their prices are expected to decline from current levels. To the extent that utility programs and other market forces lead to increased production and lower prices of more efficient lighting equipment, federal standards (i.e., those considered here) will have less impact, because there will be fewer energy savings to pursue. Alternatively, if these forces are short-lived or ineffective, greater savings could be captured by federal policy.

The following baselines were considered from which energy, economic, and environmental benefits could be measured.

1. *No Programs Case:* assumes that efficiency/price relationships remain at present levels. Consumer decisions on efficiency level are altered only by energy price changes. This baseline may be used for comparison with other forecasts of technical or achievable potential. For perspective, it is important to note that the No Programs baseline is virtually identical to a pure frozen-efficiency baseline (i.e., with no change in energy intensity, kWh/sq ft-year, for lighting) and to the current *Annual Energy Outlook* (AEO) forecast prepared by the Energy Information Administration of the U.S. DOE (6). This was not selected as the base case because current market forces and government programs are not accounted for.
2. *Base Case:* assumes that significant lighting efficiency improvements are stimulated by utility DSM programs, Environmental Protection Agency (EPA) Green Lights, Federal Energy Management Program (FEMP) Relighting, and state building codes and standards. All of these programs are assumed to persist only through 1995, but are removed thereafter, except state building codes, which persist permanently. Efficiency levels are primarily based on the Lighting Research Institute's (LRI) supply/demand survey of manufacturers, utilities, and lighting maintenance companies, which provides projections through 1995 (7). This was selected as the base case.
3. *High-Efficiency Base Case:* assumes that the features in the Base Case are present from 1990 - 2030. Efficiency levels based on the LRI survey are projected to continue through 2030, based on a combination of programs and resulting market impacts. This case was examined as a sensitivity case.

Forecasts of policy impacts compared to the latter two base cases estimate savings potential *beyond* existing programs and therefore savings are less than those from forecasts that compare with frozen-efficiency scenarios.

Figure 2.1 shows total annual electricity consumption for the commercial sector, projected from 1990 to 2030. The Base Case, which includes existing private and government programs, shows lower electricity consumption than the No Programs Case. The High-Efficiency Case, which assumes continued programs, shows lower projected electricity consumption.

Figure 2.2 shows annual lighting energy consumption. The impact of programs in both the Base Case and the High-Efficiency Case (compared to the No Programs case) is greater for lighting than for total electricity (Figure 2.1). The termination of programs in 1995 in the Base Case can be seen in the lighting consumption projection.

**Figure 2.1: Total Annual Electricity Consumption
Commercial Sector**

Figure 1

**Figure 2.2: Annual Lighting Energy Consumption
Commercial Sector**

CHAPTER 3. PROJECTED NATIONAL IMPACTS OF STANDARDS: BALLASTS

The EPRI COMMEND model (8) projects a number of economic and energy-use variables that are used to assess the impact of proposed standards on consumers, electric utilities, and appliance manufacturers. This chapter presents the model's projections, assuming various trial standards. The principal outputs from COMMEND are annual energy consumption by end use and fuel and energy use intensity (EUI, kWh/sq ft-yr) for 11 commercial building types. Differences in these quantities between a base case and each trial standards case are calculated from COMMEND output. These outputs are provided annually (or for selected years) and are summed cumulatively over a period of time, i.e., 1996-2030. Energy savings are given for each year from implementation of standards to the end of the period. COMMEND output and engineering cost data are used to evaluate the net present value of standards 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 trial standards levels analyzed. Section 3.2 presents the historical and projected energy consumption. This includes energy consumption for new lighting equipment and total national energy consumption for commercial lighting. Section 3.3 presents annual shipments of ballasts. Section 3.4 presents prices. Section 3.5 presents net present value. Section 3.6 discusses the results of the sensitivity analysis.

Volume A of this Technical Support Document gives an overview of the general COMMEND methodology and demographic assumptions. Product-specific input data are described in this volume in Appendix C.

3.1 STANDARDS LEVELS

Table 3.1 shows the correspondence between the trial standards levels, the engineering design levels, and the associated EUIs.

Table 3.1 Trial Standards Levels for Fluorescent Light Ballasts

Standard Level	1-F40	2-F40	2-F96	2-F96HO	3-F40	4-F40	1-F32T8	2-F32T8	3-F32T8	4-F32T8	1995 New Lgt. EUI (kWh/sq-yr)
Baseline	EE	EE	EE	EE	EE	EE	EE	EE	EE	EE	3.67
1	CC	CC	ER	ER	CC	CC	CC	CC	CC	CC	3.58
2	ER	ER	ER	ER	ER	ER	ER	ER	ER	ER	3.56
3	ER	ER	ER	ER	ER	ER	EI	EI	EI	EI	3.55

EE = Energy Efficient Magnetic
CC = Cathode Cutout

ER = Electronic, Rapid-Start
EI = Electronic, Instant-Start

3.2 ENERGY CONSUMPTION

Table 3.2 and Figure 3.1 show the past and projected average energy use of new lighting equipment, averaged over all commercial building types and lamp classes. The energy use intensity (EUI) of lighting is projected to increase from 4.35 kWh/sq ft-yr for new equipment bought in 1990, to 4.68 kWh/sq ft-yr in 2030 in the absence of amended standards. At standard level 3, the new EUI in 2030 is reduced to 4.06 kWh/sq ft-yr.

Table 3.2 Energy Utilization Index for New Lighting Equipment (weighted average kWh/sq ft-yr)

Year	Trial Standard Level			
	Base	1	2	3
Projected				
1990	4.35			
1995	4.05	4.04	4.04	4.03
2000	4.13	3.94	3.92	3.90
2005	4.41	4.04	3.99	3.97
2010	4.66	4.14	4.08	4.04
2015	4.71	4.17	4.10	4.07
2020	4.70	4.16	4.09	4.06
2025	4.69	4.16	4.09	4.06
2030	4.68	4.16	4.09	4.06

Source: EPRI COMMEND.

**Figure 3.1: Annual Commercial Lighting Energy Consumption
Ballast Trial Standards**

**Figure 3.2: Annual Commercial Lighting Energy Consumption
Ballast Trial Standards, Sensitivity (High Efficiency)**

Table 3.3 and Figure 3.2 present projections of total energy consumption and savings for fluorescent ballasts. Standards are projected to produce cumulative energy savings during the period 1996-2030, ranging from 13.7 Quads for standards level 1 to 17.0 Quads for standards level 3, including space-conditioning impacts.

3.3 ANNUAL INSTALLATIONS

As shown in Table 3.4, installations⁴ of fluorescent light ballasts are projected to increase from 71 million in 1995 to 133 million in 2030, based upon the projected increases in commercial floor area. COMMEND does not provide a mechanism for calculating changes in shipments with standards levels. Changes in shipments are calculated in LBL-MIM, as reported in Chapter 5.

Table 3.3 U.S. Commercial Lighting Energy Consumption (Quadrillion Btu, Primary)

Year	Trial Standard			
	Base	1	2	3
1995	3.39	3.38	3.38	3.38
2000	3.82	3.68	3.66	3.64
2005	4.44	4.13	4.08	4.06
2010	5.11	4.64	4.57	4.54
2015	5.63	5.10	5.02	4.97
2020	6.12	5.55	5.46	5.42
2025	6.66	6.04	5.94	5.90
2030	7.20	6.53	6.42	6.38
1995-2030	185.38	170.48	168.15	167.05
Savings		14.91	17.23	18.33
Total Savings (including HVAC interactions)		13.74	15.90	16.97

Source: EPRI COMMEND.

⁴ If there are no imports or exports, then annual installations are equivalent to domestic shipments. Domestic shipments can be calculated as annual installations, less imports, plus exports.

Table 3.4 Installations of Fluorescent Light Ballasts (Millions)

1995	71.6
2000	78.6
2005	85.9
2010	93.6
2015	102.8
2020	112.0
2025	122.1
2030	133.3
1995-2030	3578

Source: EPRI COMMEND.

3.4 EQUIPMENT PRICES

Projections of the purchase prices for new fluorescent ballasts in 1990 dollars are shown in Table 3.5. Prices are listed as *actual prices* and *normalized prices*. Actual prices are unit prices paid for ballasts by large commercial consumers. Normalized prices adjust actual prices to reflect differences in lumen output between the lamps used and the standard F40T12 lamp. Since the rated lumen output of the F32T8 lamp is slightly less than that of the F40T12, it is assumed that in new or renovated buildings slightly more fixtures containing ballasts and T8 lamps will be installed to provide equivalent light output. Normalized prices are used in the economic analysis. Prices are assumed to remain constant in real terms throughout the analysis period.

Table 3.5 Average Commercial Purchase Price for New Fluorescent Ballasts

Year	Base		Trial Standard Level					
			1		2		3	
1995	Actual	Normalized	Actual	Normalized	Actual	Normalized	Actual	Normalized
2-F40	13.61	13.61	18.52	18.52	22.56	22.56	22.56	22.56
2-F96	21.50	21.50	29.20	29.20	29.20	29.20	29.20	29.20
2-F96HO	36.12	36.12	40.08	40.08	40.08	40.08	40.08	40.08
2-F32T8	13.88	14.60	18.52	19.48	21.76	22.89	25.44	26.76

Source: LBL.

3.5 NET PRESENT VALUE

The net present value (NPV) to society of standards for any product is calculated by first determining the difference in present value of unit life-cycle costs between the base case and standards case each year. For each standard level, *weighted-average watt* and *weighted-average cost* per unit area are calculated based on the market distribution of product sales and the wattages and costs associated with each product class. The ratio of the weighted-average cost to the change in weighted-average watt between the base case and the standards case yields the net cost of the standard level in dollars per watt. The change in wattage due to the standards is calculated by dividing the reduction in lighting electricity use (kWh) by annual lighting hours.

The annual cost of the standard level is the product of the change in wattage times the standards cost in \$/watt. The annual costs are discounted to 1990. The NPV for the period 1996-2030 is the sum over the years of the annual values. A positive NPV of standards results when the new units in the standards case have lower present value of life-cycle cost than do new units in the base case. Table 3.6 shows the NPV to society of the trial standards levels.

Table 3.6 Net Present Value to Society of Standards for Fluorescent Ballasts Purchased from 1996-2030 (Billion 1990 Dollars, Discounted to 1990 at 7% Real)

Year	Trial Standard Level		
	1	2	3
Net Present Value (billion \$1990)	11.2	12.8	13.8

3.6 SENSITIVITY ANALYSIS

The base case and standards levels as described above constitute a reference case, or *Low-Efficiency* scenario against which the impacts of standards under different assumptions are compared. The sensitivity analysis is performed by running EPRI COMMEND for another baseline scenario, or *High-Efficiency* baseline, and forecasting the impacts of the trial standards under this baseline. For the sensitivity case, the results for the trial standards levels are compared to this baseline run and the differences are tabulated.

The reference case assumes that, until 1995, the existing utility rebates and incentives for ballasts will persist. After 1995, they will disappear with an after-effect of some cost reduction for the efficient equipment. The sensitivity scenario assumes that the utility incentives continue after 1995 at the existing level. An alternative interpretation is that a permanent change in the pricing of more efficient designs is effected in the market. The intention of this scenario was to analyze the case of a departure from the historical price/efficiency relationship, in which prices of efficient designs decline (relative to their historical values), whether due to utility programs, changes in volume manufactured, or other effects. See Chapter 2 of this volume for detailed descriptions of the baseline scenarios.

Table 3.7 Sensitivity Analysis Case

Case	Description
1	High Efficiency/Lower Equipment Prices

Table 3.8 and Figure 3.3 show the past and projected average energy use of new lighting equipment, averaged over all commercial building types and lamp classes. The EUI of lighting is projected to decrease from 4.35 kWh/sq ft-yr for new equipment bought in 1990, to 3.67 kWh/sq ft-yr in 2030 in the absence of amended standards. At standard level 3, the new EUI in 2030 is reduced to 4.05 kWh/sq ft-yr.

Table 3.9 and Figure 3.4 present projections of total consumption and energy savings for fluorescent ballasts. Standards are projected to produce cumulative energy savings during the period 1996-2030, ranging from 2.9 Quads for standards level 1 to 4.0 Quads for standards level 3, including space-conditioning impacts.

Table 3.10 shows the NPV to society of the trial standards levels for both the reference and the high-efficiency scenarios.

Table 3.8 EUI for New Lighting Equipment (Weighted-Average kWh/sq ft-yr)

Year Projected	Base	<u>Trial Standard Level</u>		
		1	2	3
1990	4.35			
1995	4.05	4.04	4.04	4.03
2000	3.81	3.77	3.76	3.75
2005	3.75	3.68	3.66	3.65
2010	3.71	3.62	3.60	3.59
2015	3.71	3.62	3.60	3.59
2020	3.69	3.61	3.59	3.58
2025	3.68	3.60	3.58	3.57
2030	3.67	3.59	3.57	3.56

Table 3.9 U.S. Commercial Lighting Energy Consumption (Quadrillion Btu, Primary)
High Efficiency Sensitivity Case

Year Projected	Base	<u>Trial Standard Level</u>		
		1	2	3
1995	3.40	3.37	3.37	3.37
2000	3.54	3.50	3.50	3.50
2005	3.84	3.77	3.74	3.74
2010	4.18	4.08	4.04	4.04
2015	4.55	4.41	4.41	4.38
2020	4.92	4.82	4.79	4.79
2025	5.36	5.22	5.19	5.19
2030	5.80	5.63	5.59	5.59
1995-2030	154.94	151.57	150.81	150.64
Savings		3.37	4.13	4.30
Total Savings (including HVAC interactions)		2.93	3.59	3.95

Source: EPRI COMMEND.

Table 3.10 Total NPV to Society for Units Sold During the Period 1996-2030 (Billion 1990 Dollars, Discounted to 1990 at 7% Real)

	Level 1	Level 2	Level 3
Reference	11.2	12.8	13.8
High Efficiency Scenario	2.5	3.0	3.3

Source: LBL.

**Figure 3.3: Average Commercial Lighting EUIs
Ballast Trial Standards**

**Figure 3.4: Average Commercial Lighting EUIs
Ballast Trial Standards, Sensitivity (High Efficiency)**

CHAPTER 4. LIFE-CYCLE COSTS AND PAYBACK PERIODS

The effect of standards on individual consumers includes a change in operating expense (usually decreased) and a change in purchase price (usually increased). The net effect is analyzed by calculating the life-cycle cost (LCC), using the engineering data (Chapter 1) for energy consumption and equipment price, and assuming the energy price projected for 1996. Section 4.1 presents the LCC for each design option. The results are displayed as graphs and as tables of values. Sections 4.2 through 4.4 show the impacts of standards on consumers. Section 4.5 presents the effect of different assumptions on the LCC calculations.

The *difference* due to standards is calculated (Sections 4.2 to 4.4) 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 standards. Then only those appliance purchasers who are impacted by standards (i.e., those who would have chosen a design eliminated by standards) are included in calculating the impact of standards on consumers. The impact of standards is expressed by three measures:

- Section 4.2: Payback Period (PBP),
- Section 4.3: Change in Life-Cycle Cost (LCC), and
- Section 4.4: Cost of Conserved Energy (CCE).

4.1 LIFE-CYCLE COST FOR DESIGN OPTIONS

The LCC is the sum of the purchase price (PC) and the operating expense (OC) discounted over the lifetime (N) of the appliance.

$$LCC = PC + \sum_{t=1}^N \frac{OC_t}{(1+r)^t} \quad (1)$$

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

$$LCC = PC + PWF \cdot OC, \quad (2)$$

where we have defined the Present Worth Factor:

$$PWF = \sum_{t=1}^N \frac{1}{(1+r)^t} = \frac{1}{r} \left[1 - \frac{1}{(1+r)^N} \right] \quad (3)$$

The LCC is calculated for each class in the year standards are imposed, using a discount rate, r .

4.1.1 LCC Data Inputs

The purchase price is based on the factory costs in the Engineering Analysis (Chapter 1) and includes a factory markup plus distributor and retailer markups, calculated by LBL-MIM. Installation and maintenance costs are also from the Engineering Analysis. Purchase price and installation costs are added to the present value of operating expenses (including maintenance, if applicable), discounted, and summed over the life of the product. Expenses in future years are discounted to the year of purchase, 1996. For the commercial sector (fluorescent light ballasts), the discount rate is 4% real, with sensitivity analysis performed at 2% and 6% real.

The energy price is the projected 1996 average commercial energy price from AEO '91 (9). Usage conditions are based on the 1986 NBECS (10) survey, namely, a weighted-average of 3642 hours/year for fluorescent lighting.

4.1.2 LCC Results

Figures 4.1 through 4.10 show the LCCs by design option. The values used to produce these figures are presented in Tables 4.1 to 4.10.

**Figure 4.1 Life Cycle Cost for a
Fluorescent Ballast (1 Lamp F40)**

Table 4.1 Life-Cycle Costs of Fluorescent Ballasts (1-Lamp F40)

Standard Design Level	No.	Design Option	Install & Maint	Retail Price	Equip-ment Price	BEF	Annual Energy Use			Life-Cycle Costs		
							Gas (MMBtu)	Elec (kWh)	Annual Energy Cost	2%	4%	6%
1 2,3	0	Energy-Efficient Magnetic	0.00	13.23	13.23	2.02	0.00	171.2	13.10	181.51	158.85	140.43
	1	0 + EE Cutout Magnetic	0.00	18.53	18.53	2.11	0.00	163.9	12.54	179.64	157.94	140.31
	2	0 + Electronic, Rapid-Start	0.00	22.53	22.53	2.50	0.00	138.4	10.59	158.57	140.25	125.36

Notes: This class represents 5.5% of the fluorescent ballasts sold in 1989;
average lifetime for all fluorescent ballasts is 15 years;
all costs are in 1990 dollars;
electricity rate is 7.65 cent/kWh (1996);
installation costs and maintenance costs are not included in the above calculations.

Figure 4.2 Life Cycle Cost for a Fluorescent Ballast (2 Lamp F40)

Table 4.2 Life-Cycle Costs of Fluorescent Ballasts (2-Lamp F40)

Standard Design Level	Design No.	Design Option	Install & Maint	Retail Price	Equip-ment Price	BEF	Annual Energy Use			Life-Cycle Costs		
							Gas (MMBtu)	Elec (kWh)	Energy Cost	2%	4%	6%
	0	Energy-Efficient Magnetic	0.00	13.61	13.61	1.09	0.00	316.9	24.24	325.11	283.15	249.06
1	1	0 + EE Cutout Magnetic	0.00	18.52	18.52	1.15	0.00	302.3	23.13	315.67	275.64	243.12
2,3	2	0 + Electronic, Rapid-Start	0.00	22.56	22.56	1.28	0.00	269.5	20.62	287.47	251.79	222.80

Notes: This class represents 40.0% of the fluorescent ballasts sold in 1989;
average lifetime for all fluorescent ballasts is 15 years;
all costs are in 1990 dollars;
electricity rate is 7.65 cent/kWh (1996);
installation costs and maintenance costs are not included in the above calculations.

**Figure 4.3 Life Cycle Cost for a
Fluorescent Ballast (2 Lamp F96)**

Table 4.3 Life-Cycle Costs of Fluorescent Ballasts (2-Lamp F96)

Standard Level	Design No.	Design Option	Install & Maint	Retail Price	Equip-ment Price	Annual Energy Use				Life-Cycle Costs		
						BEF	Gas (MMBtu)	Elec (kWh)	Annual Energy Cost	2%	4%	6%
1,2,3	0	Energy Efficient Magnetic	0.00	21.50	21.50	0.60	0.00	575.4	44.02	587.10	510.91	449.01
	1	0 + Electronic, Rapid-Start	0.00	29.20	29.20	0.72	0.00	480.7	36.77	501.71	438.06	386.35

Notes: This class represents 11.0% of the fluorescent ballasts sold in 1989;
average lifetime for all fluorescent ballasts is 15 years;
all costs are in 1990 dollars;
electricity rate is 7.65 cent/kWh (1996);
installation costs and maintenance costs are not included in the above calculations.

Figure 4.4 Life Cycle Cost for a Fluorescent Ballast (2 Lamp F96 High Output)

Table 4.4 Life-Cycle Costs of Fluorescent Ballasts (2-Lamp F96 High Output)

Standard Design Level	No.	Design Option	Install & Maint	Retail Price	Equip-ment Price	BEF	Annual Energy Use			Life-Cycle Costs		
							Gas (MMBtu)	Elec (kWh)	Annual Energy Cost	2%	4%	6%
1,2,3	0	Energy Efficient Magnetic	0.00	36.12	36.12	0.40	0.00	863.2	66.03	884.62	770.32	677.47
	1	0 + Electronic, Rapid-Start	0.00	40.08	40.08	0.50	0.00	692.0	52.94	720.29	628.67	554.23

Notes: This class represents 3.5% of the fluorescent ballasts sold in 1989;
average lifetime for all fluorescent ballasts is 15 years;
all costs are in 1990 dollars;
electricity rate is 7.65 cent/kWh (1996);
installation costs and maintenance costs are not included in the above calculations.

Figure 4.5 Life Cycle Cost for a Fluorescent Ballast (3 Lamp F40)

Table 4.5 Life-Cycle Costs of Fluorescent Ballast (3-Lamp F40)

Standard Design Level	No.	Design Option	Install & Maint	Retail Price	Equip-ment Price	Annual Energy Use				Life-Cycle Costs		
						BEF	Gas (MMBtu)	Elec (kWh)	Annual Energy Cost	2%	4%	6%
1 2,3	0	Energy Efficient Magnetic	0.00	20.42	20.42	0.71	0.00	488.0	37.33	500.11	435.49	383.00
	1	0 + EE Cutout Magnetic	0.00	27.78	27.78	0.74	0.00	466.2	35.66	486.04	424.31	374.16
	2	0 + Electronic, Rapid-Start	0.00	32.40	32.40	0.87	0.00	397.0	30.37	422.64	370.07	327.37

Notes: This class represents 5.5% of the fluorescent ballasts sold in 1989;
average lifetime for all fluorescent ballasts is 15 years;
all costs are in 1990 dollars;
electricity rate is 7.65 cent/kWh (1996);
installation costs and maintenance costs are not included in the above calculations.

Figure 4.6 Life Cycle Cost for a Fluorescent Ballast (4 Lamp F40)

Table 4.6 Life-Cycle Costs of Fluorescent Ballast (4-Lamp F40)

Standard Design Level	Design No.	Design Option	Install & Maint	Retail Price	Equip-ment Price	BEF	Annual Energy Use			Life-Cycle Costs		
							Gas (MMBtu)	Elec (kWh)	Annual Energy Cost	2%	4%	6%
1 2,3	0	Energy Efficient Magnetic	0.00	26.90	27.22	0.55	0.00	633.7	48.48	649.81	565.90	497.73
	1	0 + EE Cutout Magnetic	0.00	37.14	37.04	0.57	0.00	604.6	46.25	631.44	551.39	486.35
	2	0 + Electronic, Rapid-Start	0.00	53.56	36.96	0.67	0.00	513.6	39.29	558.41	490.41	435.16

Notes: This class represents 5.5% of the fluorescent ballasts sold in 1989;
average lifetime for all fluorescent ballasts is 15 years;
all costs are in 1990 dollars;
electricity rate is 7.65 cent/kWh (1996);
installation costs and maintenance costs are not included in the above calculations.

**Figure 4.7 Life Cycle Cost for a
Fluorescent Ballast (1 Lamp F32 T8)**

Table 4.7 Life-Cycle Costs of Fluorescent Ballast (1-Lamp F32T8)

Standard Design Level	No.	Design Option	Install & Maint	Retail Price	Equipment Price	BEF	Annual Energy Use			Life-Cycle Costs		
							Gas (MMBtu)	Elec (kWh)	Energy Cost	2%	4%	6%
1	0	Energy Efficient Magnetic	0.00	13.28	13.28	2.57	0.00	134.8	10.31	145.78	127.94	113.43
	1	0 + EE Cutout Magnetic	0.00	18.60	18.60	2.71	0.00	127.5	9.75	143.93	127.05	113.33
	2	0 + Electronic, Rapid-Start	0.00	16.12	16.12	2.97	0.00	116.5	8.91	130.64	115.21	102.68
3	3	0 + Electronic, Instant-Start	0.00	23.60	23.60	3.17	0.00	109.3	8.36	131.04	116.57	104.81

Notes: This class represents 11.5% of the fluorescent ballasts sold in 1989;
average lifetime for all fluorescent ballasts is 15 years;
all costs are in 1990 dollars;
electricity rate is 7.65 cent/kWh (1996);
installation costs and maintenance costs are not included in the above calculations.

**Figure 4.8 Life Cycle Cost for a
Fluorescent Ballast (2 Lamp F32 T8)**

Table 4.8 Life-Cycle Costs of Fluorescent Ballast (2-Lamp F32T8)

Standard Design Level	No.	Design Option	Install & Maint	Retail Price	Equip- ment Price	BEF	Annual Energy Use			Life-Cycle Costs		
							Gas (MMBtu)	Elec (kWh)	Energy Cost	2%	4%	6%
	0	Energy Efficient Magnetic	0.00	13.88	13.88	1.28	0.00	269.5	20.62	278.79	243.11	214.12
1	1	0 + EE Cutout Magnetic	0.00	18.89	18.89	1.36	0.00	254.9	19.50	269.45	235.70	208.28
2	2	0 + Electronic, Rapid-Start	0.00	21.76	21.76	1.48	0.00	233.1	17.83	250.89	220.02	194.95
3	3	0 + Electronic, Instant-Start	0.00	25.44	25.44	1.58	0.00	218.5	16.72	240.22	211.29	187.78

Notes: This class represents 5.5% of the fluorescent ballasts sold in 1989;
average lifetime for all fluorescent ballasts is 15 years;
all costs are in 1990 dollars;
electricity rate is 7.65 cent/kWh (1996);
installation costs and maintenance costs are not included in the above calculations.

**Figure 4.9 Life Cycle Cost for a
Fluorescent Ballast (3 Lamp F32 T8)**

Table 4.9 Life-Cycle Costs of Fluorescent Ballast (3-Lamp F32T8)

Standard Design Level	No.	Design Option	Install & Maint	Retail Price	Equipment Price	BEF	Annual Energy Use			Life-Cycle Costs		
							Gas (MMBtu)	Elec (kWh)	Annual Energy Cost	2%	4%	6%
	0	Energy Efficient Magnetic	0.00	20.82	20.82	0.85	0.00	404.3	30.93	418.23	364.70	321.21
1	1	0 + EE Cutout Magnetic	0.00	28.34	28.34	0.90	0.00	382.4	29.25	404.23	353.59	312.46
2	2	0 + Electronic, Rapid-Start	0.00	23.14	23.14	1.00	0.00	346.0	26.47	363.25	317.43	280.21
3	3	0 + Electronic, Instant-Start	0.00	26.34	26.34	1.06	0.00	324.1	24.79	344.92	302.01	267.14

Notes: This class represents 5.5% of the fluorescent ballasts sold in 1989;
average lifetime for all fluorescent ballasts is 15 years;
all costs are in 1990 dollars;
electricity rate is 7.65 cent/kWh (1996);
installation costs and maintenance costs are not included in the above calculations.

**Figure 4.10 Life Cycle Cost for a
Fluorescent Ballast (4 Lamp F32 T8)**

Table 4.10 Life-Cycle Costs of Fluorescent Ballast (4 Lamp F32T8)

Standard Design Level	No.	Design Option	Install & Maint	Retail Price	Equip- ment Price	BEF	Annual Energy Use			Life-Cycle Costs		
							Gas (MMBtu)	Elec (kWh)	Energy Cost	2%	4%	6%
1	0	Energy Efficient Magnetic	0.00	27.76	27.76	0.64	0.00	539.0	41.23	557.58	486.21	428.23
	1	0 + EE Cutout Magnetic	0.00	37.78	37.78	0.68	0.00	509.9	39.01	539.00	471.48	416.63
	2	0 + Electronic, Rapid-Start	0.00	34.05	34.05	0.72	0.00	480.7	36.77	506.56	442.91	391.20
3	3	0 + Electronic, Instant-Start	0.00	37.25	37.25	0.76	0.00	451.6	34.55	481.16	421.36	372.78

Notes: This class represents 5.5% of the fluorescent ballasts sold in 1989;
average life time for all fluorescent ballasts is 15 years;
all costs are in 1990 dollars;
electricity rate is 7.65 cent/kWh (1996);
installation costs and maintenance costs are not included in the above calculations.

4.2 PAYBACK PERIODS BY STANDARD 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:

$$\Delta PC + \sum_{t=1}^{PAY} \Delta OC_t = 0 \quad (4)$$

for *PAY*. 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:

$$PAY = -\frac{\Delta PC}{\Delta OC} \quad (5)$$

Numerically, the PBP is the ratio of the increase in purchase (and installation) price from the base to the standards 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.

4.2.1 PBP Data Inputs

The data inputs are the same as in Section 4.1.1, except that, in addition, a distribution of design options is projected (by COMMEND) in the base case. Only those designs that are eliminated by the standard level are included in the calculation of impacts. Consumers whose base case choice is eliminated by standards are assumed to purchase the design option corresponding to minimum compliance with the standard.

4.2.2 PBP Results

The PBPs by standard level shown in Tables 4.11 through 4.20 are the weighted averages. They compare that portion of the projected distribution of designs in the base case which are less efficient than the standards level to the design at the standards level. Designs with energy consumption at or below the standards level are not affected by the standards, so these are excluded from the calculation of impacts.

Table 4.11 shows the calculation of LCC differences, payback, and CCE. The table is composed of several parts. Table 4.11.a summarizes the equipment cost, operating cost, LCC, and energy use for each design option. Table 4.11.b shows the distribution of units sold in 1996, according to the base case forecast. In the other columns, part of this distribution is expressed as the percent of eliminated units due to standards. That is, if 78% of units sold in the base case correspond to design 0, and standard level 1 (equivalent to design 1) eliminates only design 0, then the fraction of eliminated units due to standard level 1 is 100% for design 0.

Table 4.11.c applies the weights in Table 4.11.b to the values in Table 4.11.a to obtain the weighted average values shown. Table 4.11.d shows the resulting LCC differences, PBPs, and CCE.

4.3 CHANGE IN LIFE-CYCLE COSTS DUE TO STANDARDS

The impact of standards is calculated as the difference in LCC, base case minus standards case. If the LCC difference is greater than zero (positive savings), the standard 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 standard causes a net increase in expenses to the consumer.

4.3.1 Data Inputs for Change in LCC

The data inputs are the same as in Section 4.1.1, except that, in addition, a distribution of design options is projected (by COMMEND) in the base case. Only those designs that are eliminated by the standard level are included in the calculation of impacts. Consumers whose base case choice is eliminated by standards are assumed to purchase the design option corresponding to the minimum compliance with the standard.

4.3.2 Results for Change in LCC

Tables 4.11 through 4.20 show the LCC differences by standard 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 standards level to the design at the standards level. Designs with energy consumption at or below the standards level are not affected by the standards, so these are excluded from the calculation of impacts. These LCCs are calculated at a 4% discount rate; a higher discount rate (e.g., 10%) gives a smaller difference.

Tables 4.11.d to 4.20.d show lower LCC (positive LCC difference) for all standard levels for all classes.

4.4 COST OF CONSERVED ENERGY (CCE) DUE TO STANDARDS

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:

$$CCE = -\frac{CRF \cdot \Delta PC}{\Delta E} \quad (6)$$

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.

4.4.1 CCE Data Inputs

The data inputs are the same as in Section 4.1.1, except that, in addition, a distribution of design options is projected (by COMMEND) in the base case. Only those designs that are eliminated by the standard level are included in the calculation of impacts. Consumers whose base case choice is eliminated by standards are assumed to purchase the design option corresponding to the minimum compliance with the standards.

4.4.2 CCE Results

Tables 4.11 through 4.20 show the cost of conserved energy at site of the standards levels as compared to the base case. Note that the current (1990) and projected (1996) average commercial electricity prices are 8.11 and 8.29 cents per kWh respectively (11). These are equivalent to 23.74 and 24.28 dollars per million Btu, respectively, where one kWh is taken as 3,412 Btu site energy.

Standard levels with CCEs less than projected costs of energy supply include: 1, 2, and 3.

Standard levels with CCEs greater than projected costs of energy supply include: none.

Table 4.11.a Cost and Energy Use Summary: Fluorescent Ballasts (1 Lamp @40 Watts)

Design Number	Equipment Price	Operating Cost	LCC	Annual Energy Use	
	(1990 \$)	(1990 \$)	(1990 \$)	(kWh)	(MMBtu)
0	13.23	13.10	158.85	171	0.58
1	18.53	12.54	157.94	164	0.56
2	22.53	10.59	140.25	138	0.47

Table 4.11.b Distribution of Units Sold Below Standards: Fluorescent Ballasts (1 Lamp @40 Watts)

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
0	78.18%	100.00%	85.14%	85.14%
1	13.64%	<Standard>	14.86%	14.86%
2	8.18%		<Standard>	<Standard>

Table 4.11.c Weighted Averages of Units Sold Below Standards: Fluorescent Ballasts (1 Lamp @40 Watts)

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
Equip. Price (1990 \$)	13.23	14.02	14.02
Operating Cost (1990 \$)	13.10	13.02	13.02
Life-Cycle Cost (1990 \$)	158.85	158.71	158.71
Energy Use (MMBtu/yr)	0.58	0.58	0.58

Table 4.11.d Life-Cycle Cost Differences (\$1990), Payback Periods (Year) and Cost of Conserved Energy (at 4% Real), Fluorescent Ballasts (1 Lamp @40 Watts)

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
LCC difference	0.9	18.5	18.5
Payback	9.5	3.5	3.5
CCE (cent/kWh)	6.5	2.4	2.4
CCE (\$/MMBtu)	19.1	7.1	7.1

Table 4.12.a Cost and Energy Use Summary: Fluorescent Ballasts (2 Lamps @40 Watts)

Design Number	Equipment Price	Operating Cost	LCC	Annual Energy Use	
	(1990 \$)	(1990 \$)	(1990 \$)	(kWh)	(MMBtu)
0	13.61	24.24	283.15	317	1.08
1	18.52	23.13	275.64	302	1.03
2	22.56	20.62	251.79	270	0.92

Table 4.12.b Distribution of Units Sold Below Standards: Fluorescent Ballasts (2 Lamps @40 Watts)

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
0	78.18%	100.00%	85.14%	85.14%
1	113.64%	<Standard>	14.86%	14.86%
2	8.18%		<Standard>	<Standard>

Table 4.12.c Weighted Averages of Units Sold Below Standards: Fluorescent Ballasts (2 Lamps @40 Watts)

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
Equip. Price (1990 \$)	13.61	14.34	14.34
Operating Cost (1990 \$)	24.24	24.08	24.08
Life-Cycle Cost (1990 \$)	283.15	282.03	282.03
Energy Use (MMBtu/yr)	1.08	1.07	1.07

Table 4.12.d Life-Cycle Cost Differences (\$1990), Payback Periods (year) and Cost of Conserved Energy (at 4% real) Fluorescent Ballasts (2 Lamps @40 Watts)

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
LCC difference	7.5	30.2	30.2
Payback	4.4	2.4	2.4
CCE (cent/kWh)	3.0	1.6	1.6
CCE (\$/MMBtu)	8.8	4.8	4.8

Table 4.13.a Cost and Energy Use Summary: Fluorescent Ballasts (2 Lamps @96 Watts)

Design Number	Equipment Price	Operating Cost	LCC	Annual Energy Use	
	(1990 \$)	(1990 \$)	(1990 \$)	(kWh)	(MMBtu)
0	21.50	44.02	510.91	576	1.96
1	29.20	36.77	438.06	481	1.64

Table 4.13.b Distribution of Units Sold Below Standards: Fluorescent Ballasts (2 Lamps @96 Watts)

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
0	80.00%	100.00%	100.00%	100.00%
1	20.00%	<Standard>	<Standard>	<Standard>

Table 4.13.c Weighted Averages of Units Sold Below Standards: Fluorescent Ballasts (2 Lamps @96 watts)

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
Equip. Price (1990 \$)	21.50	21.50	21.50
Operating Cost (1990 \$)	44.02	44.02	44.02
Life-Cycle Cost (1990 \$)	510.91	510.91	510.91
Energy Use (MMBtu/yr)	1.96	1.96	1.96

Table 4.13.d Life-Cycle Cost Differences (\$1990), Payback Periods (year) and Cost of Conserved Energy (at 4% real) Fluorescent Ballasts (2 Lamps @96 Watts)

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
LCC difference	72.9	72.9	72.9
Payback	1.1	1.1	1.1
CCE (cent/kWh)	0.7	0.7	0.7
CCE (\$/MMBtu)	2.1	2.1	2.1

**Table 4.14.a Cost and Energy Use Summary: Fluorescent Ballasts
(2 HO Lamps @110 Watts)**

Design Number	Equipment Price	Operating Cost	LCC	Annual Energy Use	
	(1990 \$)	(1990 \$)	(1990 \$)	(kWh)	(MMBtu)
0	36.12	66.03	770.32	863	2.95
1	40.08	52.94	628.67	692	2.36

**Table 4.14.b Distribution of Units Sold Below Standards: Fluorescent Ballast
(2 HO Lamps @110 Watts)**

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
0	80.00%	100.00%	100.00%	100.00%
1	20.00%	<Standard>	<Standard>	<Standard>

**Table 4.14.c Weighted Averages of Units Sold Below Standards: Fluorescent Ballasts
(2 HO Lamps @ 110 Watts)**

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
Equip. Price (1990 \$)	36.12	36.12	36.12
Operating Cost (1990 \$)	66.03	66.03	66.03
Life-Cycle Cost (1990 \$)	770.32	770.32	770.32
Energy Use (MMBtu/yr)	2.95	2.95	2.95

**Table 4.14.d Life-Cycle Cost Differences (\$1990), Payback Periods (year) and Cost of
Conserved Energy (at 4% real) Fluorescent Ballasts (2 HO Lamps @110 Watts)**

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
LCC difference	141.7	141.7	141.7
Payback	0.3	0.3	0.3
CCE (cent/kWh)	0.2	0.2	0.2
CCE (\$/MMBtu)	0.6	0.6	0.6

Table 4.15.a Cost and Energy Use Summary: Fluorescent Ballasts (3 Lamps @40 Watts)

Design Number	Equipment Price	Operating Cost	LCC	Annual Energy Use	
	(1990 \$)	(1990 \$)	(1990 \$)	(kWh)	(MMBtu)
0	20.42	37.33	435.49	488	1.67
1	27.78	35.66	424.31	466	1.59
2	32.40	30.37	370.07	397	1.36

Table 4.15.b Distribution of Units Sold Below Standards: Fluorescent Ballasts (3 Lamps @40 Watts)

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
0	78.18%	100.00%	85.14%	85.14%
1	13.64%	<Standard>	14.86%	14.86%
2	8.18%		<Standard>	<Standard>

Table 4.15.c Weighted Averages of Units Sold Below Standards: Fluorescent Ballasts (3 Lamps @40 Watts)

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
Equip. Price (1990 \$)	20.42	21.51	21.51
Operating Cost (1990 \$)	37.33	37.08	37.08
Life-Cycle Cost (1990 \$)	435.49	433.83	433.83
Energy Use (MMBtu/yr)	1.67	1.65	1.65

Table 4.15.d Life-Cycle Cost Differences (\$1990), Payback Periods (year) and Cost of Conserved Energy (at 4% real), Fluorescent Ballasts (3 Lamps @40 Watts)

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
LCC difference	11.2	63.8	63.8
Payback	4.4	1.6	1.6
CCE (cent/kWh)	3.0	1.1	1.1
CCE (\$/MMBtu)	8.9	3.3	3.3

Table 4.16.a Cost and Energy Use Summary: Fluorescent Ballasts (4 Lamps @40 Watts)

Design Number	Equipment Price	Operating Cost	LCC	Annual Energy Use	
	(1990 \$)	(1990 \$)	(1990 \$)	(kWh)	(MMBtu)
0	27.22	48.48	565.90	634	2.16
1	37.04	46.25	551.39	605	2.06
2	36.96	39.29	490.41	514	1.75

Table 4.16.b Distribution of Units Sold Below Standards: Fluorescent Ballasts (4 Lamps @40 Watts)

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
0	78.18%	100.00%	85.14%	85.14%
1	13.64%	<Standard>	14.86%	14.86%
2	8.18%		<Standard>	<Standard>

Table 4.16.c Weighted Averages of Units Sold Below Standards: Fluorescent Ballasts (4 Lamps @40 Watts)

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
Equip. Price (1990 \$)	27.22	28.68	28.68
Operating Cost (1990 \$)	48.48	48.15	48.15
Life-Cycle Cost (1990 \$)	565.90	563.74	563.74
Energy Use (MMBtu/yr)	2.16	2.15	2.15

Table 4.16.d Life-Cycle Cost Differences (\$1990), Payback Periods (year) and Cost of Conserved Energy (at 4% real), Fluorescent Ballasts (4 Lamps @40 Watts)

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
LCC difference	14.5	73.3	73.3
Payback	4.4	0.9	0.9
CCE (cent/kWh)	3.0	0.6	0.6
CCE (\$/MMBtu)	8.9	1.9	1.9

Table 4.17.a Cost and Energy Use Summary: Fluorescent Ballasts (1 Lamp @32 Watts)

Design Number	Equipment Price	Operating Cost	LCC	Annual Energy Use	
	(1990 \$)	(1990 \$)	(1990 \$)	(kWh)	(MMBtu)
0	13.28	10.31	127.94	135	0.46
1	18.60	9.75	127.05	128	0.44
2	16.12	8.91	115.21	117	0.40
3	23.60	8.36	116.57	109	0.37

Table 4.17.b Distribution of Units Sold Below Standards: Fluorescent Ballasts (1 Lamp @32 Watts)

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
0	24.11%	100.00%	85.44%	78.56%
1	4.11%	<Standard>	14.56%	13.39%
2	2.47%		<Standard>	8.05%
3	69.32%			<Standard>

Table 4.17.c Weighted Averages of Units Sold Below Standards: Fluorescent Ballasts (1 Lamp @32 Watts)

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
Equip. Price (1990 \$)	13.28	14.05	14.22
Operating Cost (1990 \$)	10.31	10.23	10.12
Life-Cycle Cost (1990 \$)	127.94	127.81	126.80
Energy Use (MMBtu/yr)	0.46	0.46	0.45

Table 4.17.d Life-Cycle Cost Differences (\$1990), Payback Periods (year) and Cost of Conserved Energy (at 4% real), Fluorescent Ballasts (1 Lamp @32 Watts)

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
LCC difference	0.9	12.6	10.2
Payback	9.5	1.6	5.3
CCE (cent/kWh)	6.6	1.1	3.7
CCE (\$/MMBtu)	19.2	3.2	10.7

Table 4.18.a Cost and Energy Use Summary: Fluorescent Ballasts (2 Lamps @32 Watts)

Design Number	Equipment Price	Operating Cost	LCC	Annual Energy Use	
	(1990 \$)	(1990 \$)	(1990 \$)	(kWh)	(MMBtu)
0	13.88	20.62	243.11	270	0.92
1	18.89	19.50	235.70	255	0.87
2	21.76	17.83	220.02	233	0.80
3	25.44	16.72	211.29	219	0.75

Table 4.18.b Distribution of Units Sold Below Standards: Fluorescent Ballasts (2 Lamps @32 Watts)

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
0	24.11%	100.00%	85.44%	78.56%
1	4.11%	<Standard>	14.56%	13.39%
2	2.47%		<Standard>	8.05%
3	69.32%			<Standard>

Table 4.18.c Weighted Averages of Units Sold Below Standards: Fluorescent Ballasts (2 Lamps @32 Watts)

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
Equip. Price (1990 \$)	13.88	14.61	15.19
Operating Cost (1990 \$)	20.62	20.46	20.25
Life-Cycle Cost (1990 \$)	243.11	242.03	240.26
Energy Use (MMBtu/yr)	0.92	0.91	0.90

Table 4.18.d Life-Cycle Cost Differences (\$1990), Payback Periods (year) and Cost of Conserved Energy (at 4% real), Fluorescent Ballasts (2 Lamps @32 Watts)

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
LCC difference	7.4	22.0	29.0
Payback	4.5	2.7	2.9
CCE (cent/kWh)	3.1	1.9	2.0
CCE (\$/MMBtu)	9.0	5.5	5.9

Table 4.19.a Cost and Energy Use Summary: Fluorescent Ballasts (3 Lamps @32 Watts)

Design Number	Equipment Price	Operating Cost	LCC	Annual Energy Use	
	(1990 \$)	(1990 \$)	(1990 \$)	(kWh)	(MMBtu)
0	20.82	30.93	364.70	404	1.38
1	28.34	29.25	353.59	383	1.31
2	23.14	26.47	317.43	346	1.18
3	26.34	24.79	302.01	324	1.11

Table 4.19.b Distribution of Units Sold Below Standards: Fluorescent Ballasts (3 Lamps @32 Watts)

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
0	24.11%	100.00%	85.44%	78.56%
1	4.11%	<Standard>	14.56%	13.39%
2	2.47%		<Standard>	8.05%
3	69.32%			<Standard>

Table 4.19.c Weighted Averages of Units Sold Below Standards: Fluorescent Ballasts (3 Lamps @32 Watts)

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
Equip. Price (1990 \$)	20.82	21.92	22.01
Operating Cost (1990 \$)	30.93	30.69	30.35
Life-Cycle Cost (1990 \$)	364.70	363.08	359.41
Energy Use (MMBtu/yr)	1.38	1.37	1.35

Table 4.19.d Life-Cycle Cost Differences (\$1990), Payback Periods (year) and Cost of Conserved Energy (at 4% real), Fluorescent Ballasts (3 Lamps @32 Watts)

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
LCC difference	11.1	45.7	57.4
Payback	4.5	0.3	0.8
CCE (cent/kWh)	3.1	0.2	0.5
CCE (\$/MMBtu)	9.0	0.6	1.6

Table 4.20.a Cost and Energy Use Summary: Fluorescent Ballasts (4 Lamps @32 Watts)

Design Number	Equipment Price	Operating Cost	LCC	Annual Energy Use	
	(1990 \$)	(1990 \$)	(1990 \$)	(kWh)	(MMBtu)
0	27.76	41.23	486.21	539	1.84
1	37.78	39.01	471.48	510	1.74
2	34.05	36.77	442.91	481	1.64
3	37.25	34.55	421.36	452	1.54

Table 4.20.b Distribution of Units Sold Below Standards: Fluorescent Ballasts (4 Lamps @32 Watts)

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
0	24.11%	100.00%	85.44%	78.56%
1	4.11%	<Standard>	14.56%	13.39%
2	2.47%		<Standard>	8.05%
3	69.32%			<Standard>

Table 4.20.c Weighted Averages of Units Sold Below Standards: Fluorescent Ballasts (4 Lamps @32 Watts)

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
Equip. Price (1990 \$)	27.76	29.22	29.61
Operating Cost (1990 \$)	41.23	40.91	40.57
Life-Cycle Cost (1990 \$)	486.21	484.06	480.75
Energy Use (MMBtu/yr)	1.84	1.83	1.81

Table 4.20.d Life-Cycle Cost Differences (\$1990), Payback Periods (year) and Cost of Conserved Energy (at 4% real), Fluorescent Ballasts (4 Lamps @32 Watts)

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
LCC difference	14.7	41.2	59.4
Payback	4.5	1.2	1.3
CCE (cent/kWh)	3.1	0.8	0.9
CCE (\$/MMBtu)	9.1	2.4	2.6

4.5 LCC SENSITIVITY ANALYSIS

The sensitivity of the national LCC results were tested by varying assumptions about energy prices and equipment prices. These tables 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. Projected (1992) state energy prices (12) relative to the national average were applied to the projected 1996 national average price from the *Annual Energy Outlook 1991* to obtain state prices for 1996. (This represents a wider range of prices than analyzed in previous analyses, which used 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.

Figure 4.11 and Table 4.21 summarize the results of the sensitivity analysis. They include:

- a graph of highest and lowest LCC sensitivity, and reference case, and
- a table of LCCs for all sensitivity cases. The table also shows the number of sensitivity cases for which each design option is the minimum LCC.

Figure 4.11 Sensitivity Analysis for a Fluorescent Ballast (2 Lamp F40)

Table 4.21 Sensitivity Summary of Life-Cycle Costs of a Fluorescent Ballast (2-Lamp F40)

Standard Level Design Option	0	1	2,3	Std Level @ min LCC	Design Option @ min LCC
Reference	283	276	252	2,3	2
1	162	160	148	2,3	2
2	284	277	252	2,3	2
3	162	161	149	2,3	2
4	410	397	360	2,3	2
5	282	274	251	2,3	2
6	410	395	359	2,3	2
# of cases as min LCC			7		

CHAPTER 5. IMPACTS ON THE MANUFACTURERS OF FLUORESCENT LAMP BALLASTS

5.1 LONG-RUN IMPACTS

The analysis shows that compared to the 1996 base case, the fluorescent lamp ballast industry is likely to experience a return on equity (ROE) increase at all trial standards levels. At standards level 1, there is approximately a 54% chance that ROE will increase, and with an expected increase of 0.51%. At standards level 2 there is approximately a 54% chance of an increase in ROE with an expected increase of 0.58%. At standards level 3 there is approximately a 53% chance of an increase in ROE with an expected increase of 0.59%. These results are based on 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.

5.1.1 Qualitative analysis

According to reports from within the industry, fluorescent lamp ballast manufacturing is characterized by economies of scale; this means that for the purposes of price determination there are fixed costs. Depending on the standards level considered, these are estimated to be about 10% of total costs. Since increases in fixed costs cannot be passed on, this 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 standards are imposed, and to the extent that standards induce an increase in variable costs, such costs will be more than completely passed on in the form of a price increase, which in itself is profitable, but which also tends to reduce profit because of the effect of a price increase on sales. If standards induce 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 fluorescent lamp ballasts more attractive and thereby increasing demand. 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.) The model calculates that these effects, when combined, are more likely to increase economic profits than decrease them at all standards levels.

5.1.2 Quantitative analysis

Table 5.1 summarizes all essential outputs from the LBL-MIM simulations using the primary scenario for fluorescent lamp ballasts. Six other scenarios are summarized and discussed in the sensitivity section, Section 5.4.

Once the above interpretations are understood, the results of the model concerning the long-run impact of standards on the fluorescent lamp ballast manufacturing industry can be read from the output table.

Table 5.1 Fluorescent Lamp Ballasts Output Table: Primary Scenario - Long Run

	1996 BASE	Level 1	Level 2	Level 3
Shipments (in Mil)	13.03	13.86	13.99	14.01
% change		6.30%	7.33%	7.53%
S.E.		38.19%	197.15%	93.63%
Price	\$11.06	\$13.83	\$14.20	\$14.25
% change		25.03%	28.36%	28.86%
S.E.		17.82%	19.27%	18.70%
Revenue (in \$M)	144.18	191.62	198.63	199.78
% change		32.91%	37.76%	38.56%
S.E.		50.99%	252.42%	118.05%
Net Income (in \$M)	1.15	1.26	1.28	1.28
Difference		0.11	0.13	0.13
S.E.		26.16	146.76	81.20
ROE	15.53%	16.03%	16.11%	16.12%
Difference		0.51%	0.58%	0.59%
S.E.		5.34%	6.70%	7.29%

5.2 SHORT-RUN IMPACTS

The business cycle presents the fluorescent lamp ballast manufacturing industry with fairly sharp periodic fluctuations in demand, much larger than the fluctuations predicted for any of the standards levels. These normal demand fluctuations present the same types of opportunities for price competition that will accompany fluctuations resulting from a change in standards. 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 fluorescent lamp ballasts; a 10% demand increase has the reverse effect. This effect is taken into account as described in Volume A, Chapter 3, Section 3.3.4.2 of this Technical Support Document, and is used to produce a short-run version of the output table that is displayed in Table 5.2. For reasons that are explained in the above reference, the short-run change has been overestimated. Thus the values for change in Table 5.2 should be viewed as somewhat too large in absolute value.

Table 5.2 Fluorescent Lamp Ballasts Output Table: Primary Scenario - Short Run

	1996 BASE	Level 1	Level 2	Level 3
Shipments (in Mil)	13.03	13.84	13.98	14.00
% change		6.22%	7.24%	7.44%
Price	\$11.06	\$13.90	\$14.27	\$14.33
% change		25.64%	29.03%	29.55%
Revenue (in \$M)	144.18	192.42	199.51	200.68
% change		33.46%	38.37%	39.19%
Net Income (in \$M)	1.15	1.86	1.94	1.96
Difference		0.71	0.79	0.81
ROE	15.53%	23.67%	24.50%	24.67%
Difference		8.14%	8.98%	9.15%
S.E.		200.29%	262.55%	261.91%

5.3 IMPACT AS A FUNCTION OF FIRM SIZE

Generally, we find that in this industry, average cost tends to decrease with increasing firm size. That is, 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 consolidation that has occurred over time. The fact that the consolidation has been producing larger firms, to the point where three firms account for 90% of the market, 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 be, on average, in more danger of failing or being bought out than will the larger firms. Because of the greater precariousness 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.

Most (if not all three) of the standards levels considered do not require significant retooling of plant and equipment. Further, much of the industry is currently retooling in anticipation of future growth, due in part to demand fueled by demand-side management programs.

These factors combined with the estimates that the industry will be better at all standards levels implies that there will probably not be significant adverse impacts on small firms.

5.4 SENSITIVITY ANALYSIS FOR FLUORESCENT LAMP BALLASTS

The three following subsections discuss different aspects of the sensitivity analysis conducted by LBL-MIM. The first subsection, on sensitivity charts, shows the implications of the uncertainty of each control variable for the prediction of ROE. The next subsection shows six alternative scenarios that are of particular importance and deserve a more detailed analysis than those randomly generated by Monte Carlo runs. The last subsection shows the use of Monte Carlo runs to find combinations of errors that would cause the change in ROE to be considerably more negative than is predicted.

5.4.1 Sensitivity Charts

Table 5.3 lists the sensitivity of ROE to a one standard error change in the control panel inputs. The variables analyzed are industry price elasticity of demand (IPE), discount rate (RD), the equity cost of capital (ECC), economic profit (EP), the fixed part of costs (FCA), the fixed part of one-time costs (FIX), one-time capital costs (CC.N), one-time variable costs (dVC.N), and the shape parameter of the demand curve (ro.N).

Table 5.3 Fluorescent Lamp Ballasts Sensitivity Chart: Primary Scenario (Sensitivity of ROE to 1 S.E. Change in Control Variable)

Control Variables			Possible Standards Levels		
Name	Value	Changed	1	2	3
IPE	-0.080	-0.184	5.23%	5.96%	6.10%
RD	25.00%	57.48%	-1.15%	-1.35%	-1.40%
ECC	0.090	0.099	0.00%	0.00%	0.00%
EP	0.059	0.069	-0.05%	-0.05%	-0.05%
FCA	0.101	0.163	0.50%	0.58%	0.59%
FIX	0.113	0.196	-0.02%	-0.03%	-0.03%
CC.N	0.181	0.221	0.00%	0.01%	0.01%
dVC.N	6.120	8.209	-0.18%	-0.19%	-0.20%
ro.N	0.000	0.100	0.84%	0.96%	0.98%

As can be seen from the table, four 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 (RD), which give the industry operating cost elasticity, (3) fixed part of costs and assets (FCA), and (4) the shape parameter of the demand curve (ro.N). The reasons that these four variables are important are discussed below.

5.4.2 Alternative Scenarios

The sensitivity analysis shows that both price and operating cost elasticities (the latter being derived from the discount rate) play crucial roles in determining the model's output. These are both *industry* elasticities as opposed to single-firm elasticities; this means they measure the effect on demand of a change in price by all firms and a change in operating cost of all fluorescent lamp ballasts. The estimates of standard errors that 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, six alternative scenarios have been run. The six scenarios include low- and high-price elasticity scenarios, a constant shipments scenario (i.e., industry price and operating cost elasticity set to zero), high- and low-discount rate scenarios (i.e., high- and low-operating cost scenarios), and a low-discount rate and high-price elasticity scenario. Tables 5.4 through 5.9 show the results of running these six scenarios for the fluorescent lamp ballast manufacturing industry.

In these alternative scenarios, note the impact of a change in the discount rate. A high RD input value lowers ROE, and a lower RD value increases ROE. Because markup is determined by price elasticity, it will tend to change as the ratio of price to operating cost changes. Standards will always increase this ratio, which decreases markup. This effect is strongest when appliance demand is relatively elastic with respect to operating cost. That is, a more elastic operating cost elasticity will result in a greater decrease in markup under standards, resulting in a greater decrease in profitability.

The other tables show that increasing price elasticity also tends to lower ROE. This effect is due to the greater decline in shipments when price elasticity is greater.

The percentage of fixed costs (FCA) is important because of its role in the model. It determines the LBL-MIM's estimate of the markup over variable cost, which, in turn, determines the firm's ability to pass on various combinations of fixed and variable costs. For a more detailed explanation, see Volume A, Appendix C.

5.4.3 Monte Carlo Analysis

The Monte Carlo approach is described in Volume A, Chapter 3, Section 3.4.3, and the standard errors it generates are reported in Tables 5.4 through 5.9. Table 5.10 shows the control panels from two Monte Carlo runs, which were selected because they show a decrease in long-run ROE. Both Monte Carlo runs were done for standards level 3. In the first scenario, a significantly higher demand curve parameter reduces profitability.

The shape of the demand curve parameter (ro.N) plays a role under certain circumstances. The demand function is specified as a function of life-cycle cost (i.e., of purchase price and operating cost). If purchase price plays a relatively large role in the demand function, then demand is less sensitive to changes in the shape parameter since in the limit, demand would be a function of purchase price. Hence the shape parameter plays a larger role when operating cost and price play relatively equal roles in determining life-cycle cost. Also, it depends on how

much of a change in operating costs results from a particular standards level under consideration. This is because a large change in operating cost will shift demand to a very different part of the demand curve.

In the second run, a higher percentage of both fixed costs (FCA) and a higher proportion of fixed one-time costs (F1X) (neither of which are passed through in prices) were the primary factors in reducing ROE.

Table 5.4 Fluorescent Ballasts Output Table: Low-Price-Elasticity Scenario - Long Run

	1996 BASE	Level 1	Level 2	Level 3
Shipments (in Mil)	14.03	15.85	16.16	16.22
% change		13.00%	15.19%	15.62%
S.E.		4.84%	5.15%	5.61%
Price	\$11.06	\$13.83	\$14.20	\$14.25
% change		25.03%	28.36%	28.86%
S.E.		17.31%	17.94%	19.51%
Revenue (in \$M)	155.21	219.29	229.49	231.26
% change		41.28%	47.86%	49.00%
S.E.		12.86%	13.39%	14.14%
Net Income (in \$M)	1.71	2.35	2.45	2.48
Difference		0.63	0.74	0.76
S.E.		0.42	0.47	0.47
ROE	21.66%	26.31%	26.98%	27.10%
Difference		4.66%	5.32%	5.45%
S.E.		3.79%	4.11%	4.08%

Table 5.5 Fluorescent Ballasts Output Table: High-Price Elasticity Scenario - Long Run

	1996 BASE	Level 1	Level 2	Level 3
Shipments (in Mil)	12.10	12.10	12.10	12.10
% change		0.01%	0.01%	0.01%
S.E.		0.00%	0.00%	0.00%
Price	\$11.06	\$13.83	\$14.20	\$14.25
% change		25.03%	28.36%	28.86%
S.E.		18.61%	17.96%	19.35%
Revenue (in \$M)	133.94	167.48	171.94	172.62
% change		25.04%	28.37%	28.87%
S.E.		18.60%	17.96%	19.35%
Net Income (in \$M)	0.61	0.30	0.25	0.24
Difference		-0.32	-0.36	-0.37
S.E.		0.21	0.24	0.24
ROE	8.96%	4.38%	3.67%	3.54%
Difference		-4.59%	-5.29%	-5.43%
S.E.		3.07%	3.47%	3.44%

Table 5.6 Fluorescent Ballasts Output Table: Constant-Shipments Scenario - Long Run

	1996 BASE	Level 1	Level 2	Level 3
Shipments (in Mil)	12.10	12.10	12.10	12.10
% change		0.00%	0.00%	0.00%
S.E.		0.00%	0.00%	0.00%
Price	\$11.06	\$13.83	\$14.20	\$14.25
% change		25.03%	28.36%	28.86%
S.E.		17.94%	19.04%	19.48%
Revenue (in \$M)	133.93	167.45	171.91	172.59
% change		25.03%	28.36%	28.86%
S.E.		17.94%	19.04%	19.48%
Net Income (in \$M)	0.61	0.30	0.25	0.24
Difference		-0.32	-0.36	-0.37
S.E.		0.21	0.25	0.23
ROE	8.96%	4.36%	3.66%	3.52%
Difference		-4.59%	-5.30%	-5.44%
S.E.		3.09%	3.60%	3.39%

Table 5.7 Fluorescent Ballasts Output Table: Low-Discount-Rate Scenario - Long Run

	1996 BASE	Level 1	Level 2	Level 3
Shipments (in Mil)	17.30	23.59	24.74	24.96
% change		36.33%	43.00%	44.26%
S.E.		4.08%	4.74%	5.29%
Price	\$11.04	\$13.79	\$14.16	\$14.21
% change		24.92%	28.23%	28.74%
S.E.		16.24%	18.24%	18.12%
Revenue (in \$M)	191.02	325.31	350.27	354.75
% change		70.30%	83.37%	85.72%
S.E.		18.57%	21.49%	21.21%
Net Income (in \$M)	3.36	6.00	6.47	6.56
Difference		2.64	3.11	3.20
S.E.		1.24	1.56	1.54
ROE	34.50%	45.49%	46.81%	47.03%
Difference		10.98%	12.30%	12.53%
S.E.		7.12%	8.67%	8.48%

Table 5.8 Fluorescent Ballasts Output Table: High-Discount-Rate Scenario - Long Run

	1996 BASE	Level 1	Level 2	Level 3
Shipments (in Mil)	11.91	11.74	11.72	11.72
% change		-1.38%	-1.55%	-1.57%
S.E.		1.82%	1.86%	1.78%
Price	\$11.17	\$14.02	\$14.40	\$14.46
% change		25.58%	28.99%	29.50%
S.E.		18.79%	19.28%	18.17%
Revenue (in \$M)	132.99	164.69	168.88	169.52
% change		23.84%	26.99%	27.48%
S.E.		15.95%	16.29%	15.39%
Net Income (in \$M)	1.33	1.60	1.63	1.63
Difference		0.27	0.30	0.31
S.E.		0.52	0.56	0.48
ROE	19.59%	23.88%	24.39%	24.45%
Difference		4.29%	4.80%	4.86%
S.E.		8.25%	8.98%	7.69%

Table 5.9 Fluorescent Ballasts Output Table: Low-Discount-Rate and High-Price-Elasticity Scenario - Long Run

	1996 BASE	Level 1	Level 2	Level 3
Shipments (in Mil)	24.72	45.94	50.54	51.44
% change		85.86%	104.47%	108.10%
S.E.		17.34%	22.04%	23.64%
Price	\$11.04	\$13.79	\$14.16	\$14.21
% change		24.92%	28.23%	28.74%
S.E.		17.95%	17.60%	18.90%
Revenue (in \$M)	272.94	633.69	715.65	731.22
% change		132.17%	162.20%	167.90%
S.E.		26.64%	33.97%	35.04%
Net Income (in \$M)	7.51	17.70	19.84	20.25
Difference		10.18	12.33	12.74
S.E.		4.60	5.46	6.26
ROE	54.40%	69.46%	70.84%	71.06%
Difference		15.06%	16.44%	16.66%
S.E.		10.29%	11.08%	12.33%

Table 5.10 Fluorescent Lamp Ballasts Monte Carlo Runs: Searching for Low ROE

Scenario: Primary			Standard Level = 3		
FLUORESCENT LAMP BALLASTS	Input		Vari-	Program	
CONTROL FACTORS	Value	Cntrl	ation	Value	Name
Price Elasticity	-0.080	-1.62	30%	-0.021	IPE
Consumer Discount Rate	25.00%	-0.05	30%	23.91%	RD
Equity Cost of Capital	0.090	0.66	10%	0.096	ECC
Economic Profit	0.059	0.44	1%	0.063	EP
L-R Fixed Part of Costs & Assets	0.101	-0.33	50%	0.087	FCA
L-R Fixed Part of 1-X Cap. Cost	0.129	-0.64	60%	0.091	FIX
One-Time Capital Costs	0.245	0.14	20%	0.252	CC.N
Unit Variable Cost Increase	\$6.55	0.22	30%	6.991	dVC.N
Elasticity Curve Parameter	0.000	-0.41	10%	-0.041	ro.N
Short-Run Price Response to Demand	0.034	-1.50	353%	0.001	SRPR
	NAECA	NEW		PRVIOUS	NEW
SUMMARY	BASE	L-RUN	CHANGE	CHANGE	S-RUN
Shipments	12.36	12.60	1.92%	7.53%	12.60
Price	\$11.07	\$14.70	32.88%	28.86%	\$14.70
Revenue (in \$M)	136.75	185.19	35.43%	38.56%	185.20
Net Income	0.84	0.62	-0.22	0.13	0.61
ROE	11.99%	8.71%	-3.29%	0.59%	8.57%

Scenario: Primary			Standard Level = 3		
FLUORESCENT LAMP BALLASTS	Input		Vari-	Program	
CONTROL FACTORS	Value	Cntrl	ation	Value	Name
Price Elasticity	-0.080	-1.53	100%	-0.022	IPE
Consumer Discount Rate	25.00%	-0.34	100%	18.83%	RD
Equity Cost of Capital	0.090	0.72	10%	0.097	ECC
Economic Profit	0.059	0.78	1%	0.066	EP
L-R Fixed Part of Costs & Assets	0.101	0.45	50%	0.125	FCA
L-R Fixed Part of 1-X Cap. Cost	0.129	0.54	60%	0.175	FIX
One-Time Capital Costs	0.245	-0.04	20%	0.243	CC.N
Unit Variable Cost Increase	\$6.55	1.98	30%	11.720	dVC.N
Elasticity Curve Parameter	0.000	-0.86	10%	-0.086	ro.N
Short-Run Price Response to Demand	0.034	-0.54	353%	0.011	SRPR
	NAECA	NEW		PRVIOUS	NEW
SUMMARY	BASE	L-RUN	CHANGE	CHANGE	S-RUN
Shipments	12.49	12.66	1.41%	7.53%	12.66
Price	\$11.03	\$19.41	75.90%	28.86%	\$19.42
Revenue (in \$M)	137.78	245.79	78.39%	38.56%	245.90
Net Income	0.75	0.59	-0.16	0.13	0.65
ROE	10.53%	8.17%	-2.36%	0.59%	9.04%

CHAPTER 6. IMPACTS OF STANDARDS ON ELECTRIC UTILITIES: BALLASTS

6.1 INTRODUCTION

Appliance efficiency standards 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 standard levels. The fourth section presents the results of the revenue loss calculation. The fifth section presents a sensitivity analysis. More details on methodology may be found in Appendix E of Volume A.

6.2 AVOIDED ENERGY AND AVOIDED RELIABILITY COSTS

Figure 6.1 shows avoided energy and reliability costs for electricity savings from ballasts. These figures show the sum of avoided costs for the base-, high-, and low-energy-price cases.⁵ The value per million Btu (MMBtu) of avoided reliability costs is the same in all three energy-price cases. The avoided fuel and capital component depends on fuel prices and varies among the three cases. As explained in Appendix E of Volume A, this component implicitly contains the costs avoided when baseload power plants are deferred or canceled (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. They are used in the LBL-REM to value electricity savings from the societal perspective.

6.3 PEAK LOAD AND CAPACITY REDUCTIONS

Table 6.1 shows peak load reductions for ballasts for the relevant standard levels. Table 6.2 shows capacity savings for ballasts for the relevant standard levels. The base case peak load in the second column of Table 6.1 represents coincident peak load of all such devices in the commercial sector.

⁵ Fuel price forecasts for the period 1990 to 2000 are taken from the DOE/EIA *Annual Energy Outlook*, 1991 (DOE/EIA-0383(91)). The forecasts for years after 2000 were linearly extrapolated using the methodology described in Volume A. The high (low) energy price case is derived by increasing (decreasing) the reference case AEO fuel price forecasts for gas and coal by 5%.

Table 6.1 Peak Demand Reductions (GW) - Ballasts

Year	Peak Load	Peak Demand Savings		
		Level 1	Level 2	Level 3
1996	65.0	0.2	0.3	0.3
1997	66.7	0.8	0.9	1.0
1998	68.3	1.4	1.6	1.7
1999	69.9	2.0	2.3	2.5
2000	71.5	2.6	3.0	3.3
2001	73.8	3.2	3.7	4.0
2002	76.1	3.9	4.5	4.8
2003	78.4	4.5	5.2	5.5
2004	80.7	5.0	5.8	6.2
2005	83.1	5.6	6.5	6.9
2006	85.6	6.2	7.1	7.6
2007	88.1	6.7	7.8	8.3
2008	90.6	7.3	8.5	9.1
2009	93.1	7.9	9.2	9.8
2010	95.6	8.5	9.8	10.4
2011	97.5	9.0	10.4	11.1
2012	99.5	9.2	10.6	11.3
2013	101.4	9.3	10.8	11.5
2014	103.4	9.5	11.0	11.7
2015	105.3	9.6	11.1	11.9
2016	107.2	9.8	11.3	12.0
2017	109.0	9.9	11.5	12.2
2018	110.9	10.1	11.6	12.4
2019	112.7	10.2	11.8	12.6
2020	114.6	10.4	12.0	12.8
2021	116.6	10.5	12.1	12.9
2022	118.6	10.7	12.3	13.1
2023	120.6	10.8	12.5	13.3
2024	122.7	11.0	12.7	13.5
2025	124.7	11.1	12.9	13.7
2026	126.7	11.2	13.0	13.8
2027	128.7	11.0	12.7	13.6
2028	130.7	10.7	12.5	13.4
2029	132.7	10.5	12.3	13.2
2030	134.8	10.3	12.1	13.0

Figure 6.1 Utility Avoided Costs for Ballasts

Table 6.2 Capacity Savings (GW) - Ballasts

Year	Capacity Savings		
	Level 1	Level 2	Level 3
1996	0.1	0.2	0.2
1997	0.6	0.7	0.7
1998	1.0	1.1	1.2
1999	2.4	2.8	3.0
2000	3.2	3.6	3.9
2001	3.9	4.5	4.8
2002	4.6	5.4	5.7
2003	5.3	6.2	6.6
2004	6.0	7.0	7.5
2005	6.7	7.8	8.3
2006	7.4	8.6	9.1
2007	8.1	9.4	10.0
2008	8.8	10.2	10.9
2009	9.5	11.0	11.8
2010	10.2	11.7	12.5
2011	10.8	12.5	13.3
2012	11.0	12.7	13.6
2013	11.2	12.9	13.8
2014	11.4	13.2	14.0
2015	11.6	13.4	14.2
2016	11.8	13.6	14.4
2017	11.9	13.7	14.6
2018	12.1	14.0	14.9
2019	12.3	14.2	15.1
2020	12.5	14.4	15.3
2021	12.6	14.6	15.5
2022	12.8	14.8	15.8
2023	13.0	15.0	16.0
2024	13.2	15.2	16.2
2025	13.4	15.4	16.4
2026	13.5	15.6	16.6
2027	13.2	15.3	16.4
2028	12.9	15.0	16.1
2029	12.6	14.8	15.9
2030	12.3	14.5	15.7

The total peak demand and the savings are calculated using the appropriate conservation load factors, a T&D loss factor of 1.075, and estimates of energy consumption calculated using the LBL-REM. Capacity savings are peak load savings in regions that need additional capacity, multiplied by 1.2 to account for reserve margin needed for adequate reliability. The amount of capacity saved can be somewhat less than the peak demand savings in years before 1999 because capacity savings are only counted in regions that need capacity. After 1998, capacity savings

consistently exceed peak load savings by the reserve margin of 20% (numbers may not exactly correspond to this rule because of rounding errors).

Peak demand reductions from the standards for ballasts range from 2.6 to 3.3 GW in 2000, and from 10.3 to 13.0 GW in 2030. Capacity savings for ballasts range from 3.2 to 3.9 GW in 2000, and from 12.3 to 15.7 GW in 2030.

6.4 REVENUE LOSSES

Appliance standards allow utilities to avoid the variable costs of generating electricity, but standards also reduce electricity sales. In a 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 standards 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, use the most current information on the impacts of appliance efficiency standards.

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 standards 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 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 standards, 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 standards 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-standard sales forecast, this case is included as an absolute upper bound. Figure 6.2 shows annual revenue losses and avoided costs over time for level 3 standards, and Table 6.3 shows net revenue losses for all standards levels. Cumulative net revenue losses for ballasts range from \$0.4 to 1.2 billion.

Figure 6.2

Revenue Reductions and Avoided Costs for Ballasts

Table 6.3 Net Revenue Losses - Ballasts (Million 1990 \$)

Year	Net Revenue Losses		
	Level 1	Level 2	Level 3
1996	38	46	54
1997	131	156	167
1998	220	258	275
1999	258	300	323
2000	325	376	402
2001	374	433	463
2002	415	482	515
2003	444	515	550
2004	462	535	573
2005	471	544	580
2006	486	562	599
2007	495	572	610
2008	501	581	619
2009	501	579	618
2010	490	567	604
2011	463	534	570
2012	412	474	506
2013	357	411	438
2014	300	346	369
2015	241	278	297
2016	181	209	223
2017	119	138	147
2018	56	65	69
2019	-9	-11	-12
2020	-77	-89	-95
2021	-147	-170	-181
2022	-219	-253	-269
2023	-293	-338	-360
2024	-369	-426	-455
2025	-447	-516	-550
2026	-524	-606	-646
2027	-585	-679	-726
2028	-643	-750	-804
2029	-698	-818	-879
2030	-749	-883	-952
Total	2979	3423	3640

The figures 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. Total residential rates would increase 0.5% and 0.7% (0.04¢/kWh and 0.05¢/kWh) in 2000 and 2005, respectively, if ballasts are subject to level 3 standards and regulators only change commercial rates to compensate for any loss in revenue.

Table 6.4 shows the present value of net revenue losses at a 5% real utility discount rate for all standard 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 6.4 Present Value of Revenue Losses - Ballasts (Million 1990 \$)

Regulatory Lag	Level 1	Level 2	Level 3
None	0	0	0
1996-2001	636	744	800
1996-2030	2689	3114	3326

For ballasts, the present value of net lost revenues may range from \$636 to 800 million for a five-year lag, and would be as large as \$3.4 billion if the regulators did not make adjustments. The present values over the period 1996 to 2030 also represent the rate increases needed over this period to compensate for lost revenues, assuming that regulators adjust immediately.

6.5 SENSITIVITY ANALYSIS

Table 6.5 shows the peak demand reductions and capacity savings for sensitivity case 5. Table 6.6 shows the present value of net lost revenues for the same sensitivity case. The assumptions for the sensitivity case are the same as those for previous tables.

Table 6.5 Peak Demand Reductions and Capacity Savings (GW) - Ballasts (Sensitivity Cases)

Year	Peak Demand Reductions	Capacity Savings
1996	0.3	0.2
2000	1.0	1.2
2010	2.5	3.0
2020	2.8	3.4
2030	3.0	3.6

Table 6.6 Present Value of Net Lost Revenues (Million 1990 \$) - Ballasts (Sensitivity Cases)

Regulatory Lag	Case 5
None	0
1996-2001	311
1996-2030	986

CHAPTER 7. ENVIRONMENTAL EFFECTS

7.1 INTRODUCTION

The environmental effects from a range of new candidate energy conservation standards for fluorescent ballasts are presented here. The results are presented for each potential standard level. Each measure of possible environmental change is an alternative action, and it is compared to what is expected to happen if no new standards for fluorescent ballasts are finalized, i.e., the "no action" alternative.

The main environmental concern addressed is emissions from fossil-fueled electricity generation. All of the design options for fluorescent ballasts result in decreased electricity use and, therefore, a reduction of power plant emissions. The proposed efficiency standards will 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, or 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 is considered an environmental hazard because it contributes to the "greenhouse effect" by trapping heat energy from the earth that is emitted as infrared radiation. The "greenhouse effect" is expected to gradually raise the mean global temperature. The effect of reducing the electricity consumption of fluorescent ballasts also has an impact on the amount of heating, cooling and ventilation that is required by commercial buildings. The environmental effects resulting from changes in the space conditioning and ventilation building requirements are captured in the environmental analysis of fluorescent ballasts.

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

The following tabular results indicate what changes can be brought about in the amounts of emitted CO_2 , SO_2 , and NO_x by imposing efficiency standards for fluorescent ballasts. A table is presented for each of the appliance's trial standard levels. Each table details the changes that occur to each of the three emissions (i.e., CO_2 , SO_2 , and NO_x) through the imposition of a specific trial standard level. Each table includes the following information for a specific year between 1996 and 2030: the amount of emission abated from power plant generation, the amount abated from in-home generation, the net change in the emission, 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 1996 and 2030).

Decreases in the amounts of CO₂, SO₂, and NO_x are presented for two baseline cases: a reference case and a sensitivity (high-efficiency base) case. Trial standards levels 1 through 3 for the reference case are summarized in Tables 7.1 through 7.3 while trial standards levels 1 through 3 for the sensitivity (high-efficiency base) case are summarized in Tables 7.4 through 7.6. For an explanation of the differences in the two cases, refer to Chapter 2 of this volume.

7.2.1 Sulfur and Nitrogen Oxide Emissions

Reference Case

SO₂ emissions would be decreased by a cumulative total of up to 2.99 million tons between 1996 and 2030 in the level 3 scenario. In the year 1996, decreases in SO₂ will represent about 0.06% of the SO₂ emissions estimated to come from power plants in that year. In the year 2030, decreases in SO₂ emissions will represent about 1.18% of the SO₂ emissions estimated to come from power plants in that year. Because of provisions in the Clean Air Act Amendments (Pub. L. 101-549, November 15, 1990), the possible reductions of SO₂ that are caused by standards can be earned as credits by the utility realizing the reductions. To the extent SO₂ credits are used for future emissions, the net effect on SO₂ emissions from standards would be only a postponement of those SO₂ emissions.

Level 3 design changes to fluorescent ballasts would result in an estimated decrease in NO_x emissions of 2.74 million tons between 1996 and 2030. NO_x decreases would represent 0.06% and 1.18% of the NO_x emissions estimated to come from power plants in the years 1996 and 2030, respectively.

Sensitivity Case: High-Efficiency Base Case

SO₂ emissions would be decreased by a cumulative total of up to 0.72 million tons between 1996 and 2030 in the level 3 scenario. In the year 1996, decreases in SO₂ will represent about 0.06% of the SO₂ emissions estimated to come from power plants in that year. In the year 2030, decreases in SO₂ emissions will represent about 0.28% of the SO₂ emissions estimated to come from power plants in that year. As discussed above, the possible reductions of SO₂ emissions caused by standards can be earned as credits. To the extent credits are used for future emissions, the standards' net effect on those SO₂ emissions would be only a postponement.

Level 3 design changes to fluorescent ballasts would result in an estimated decrease in NO_x emissions of 0.65 million tons between 1996 and 2030. NO_x decreases would represent 0.06% and 0.27% of the NO_x emissions estimated to come from power plants in the years 1996 and 2030, respectively.

7.2.2 Carbon Dioxide Emissions

Reference Case

The cumulative reduction in CO₂ emissions from level 3 design changes is 1450 million tons of CO₂. For the year 1996, the estimated CO₂ reduction is 1325 thousand tons of CO₂ or about 0.06% of estimated U.S. total CO₂ emissions in 1996. For the year 2030, the estimated CO₂ reduction is 56,050 thousand tons of CO₂ or about 1.17% of estimated U.S. total CO₂ emissions in 2030.

Sensitivity Case: High Efficiency Base Case

The cumulative reduction in CO₂ emissions from level 3 design changes is 338 million tons of CO₂. For the year 1996, the estimated CO₂ reduction is 1419 thousand tons of CO₂ or about 0.06% of estimated U.S. total CO₂ emissions in 1996. For the year 2030, the estimated CO₂ reduction is 12,957 thousand tons of CO₂ or about 0.27% of estimated U.S. total CO₂ emissions in 2030.

Table 7.1
Reduction of Pollutants for Fluorescent Ballasts (Reference Case) - Level One

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	990	-41	949	0.04%
2000	11,763	-503	11,260	0.45%
2005	25,359	-1,014	24,345	0.85%
2010	38,414	-1,470	36,945	1.15%
2015	43,599	-1,583	42,016	1.17%
2020	46,741	-1,596	45,145	1.14%
2025	49,630	-1,629	48,001	1.09%
2030	45,414	-1,270	44,144	0.92%

Cumulative CO2 reduction, 1996-2030 = 1,174 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	5,557	-16	5,542	0.04%
2000	42,244	-219	42,025	0.47%
2005	77,068	-423	76,645	0.88%
2010	100,233	-595	99,639	1.19%
2015	91,646	-610	91,035	1.20%
2020	78,998	-595	78,403	1.17%
2025	65,090	-595	64,496	1.11%
2030	45,372	-673	44,699	0.93%

Cumulative SO2 reduction, 1996-2030 = 2,417,491 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. NOx Power Plant Emissions
1996	3,489	-38	3,451	0.04%
2000	31,448	-459	30,990	0.46%
2005	62,009	-926	61,082	0.87%
2010	87,107	-1,344	85,763	1.17%
2015	84,970	-1,451	83,519	1.19%
2020	78,998	-1,465	77,533	1.16%
2025	71,316	-1,497	69,820	1.11%
2030	55,770	-1,146	54,624	0.93%

Cumulative NOx reduction, 1996-2030 = 2,218,305 tons

Table 7.2
Reduction of Pollutants for Fluorescent Ballasts (Reference Case) - Level Two

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	1,188	-61	1,127	0.05%
2000	13,595	-580	13,015	0.52%
2005	29,343	-1,174	28,169	0.98%
2010	44,377	-1,693	42,683	1.33%
2015	50,313	-1,826	48,488	1.35%
2020	53,917	-1,845	52,072	1.31%
2025	57,310	-1,875	55,435	1.26%
2030	53,506	-1,516	51,990	1.08%

Cumulative CO2 reduction, 1996-2030 = 1,358 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	6,669	-31	6,638	0.05%
2000	48,823	-250	48,572	0.54%
2005	89,174	-485	88,689	1.02%
2010	115,791	-673	115,118	1.37%
2015	105,761	-704	105,057	1.38%
2020	91,127	-689	90,438	1.35%
2025	75,162	-673	74,489	1.28%
2030	53,457	-751	52,706	1.10%

Cumulative SO2 reduction, 1996-2030 = 2,797,165 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	%U.S. NOx Power Plant Emissions
1996	4,186	-55	4,131	0.05%
2000	36,346	-529	35,816	0.53%
2005	71,749	-1,073	70,676	1.01%
2010	100,628	-1,550	99,078	1.36%
2015	98,056	-1,673	96,383	1.38%
2020	91,127	-1,693	89,434	1.33%
2025	82,352	-1,723	80,628	1.28%
2030	65,708	-1,373	64,335	1.09%

Cumulative NOx reduction, 1996-2030 = 2,566,401 tons

Table 7.3
Reduction of Pollutants for Fluorescent Ballasts (Reference Case) - Level Three

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	1,386	-61	1,325	0.06%
2000	14,560	-622	13,938	0.56%
2005	31,286	-1,252	30,035	1.05%
2010	47,309	-1,807	45,503	1.41%
2015	53,622	-1,950	51,672	1.44%
2020	57,505	-1,975	55,530	1.40%
2025	61,054	-1,999	59,055	1.35%
2030	57,695	-1,645	56,050	1.17%

Cumulative CO2 reduction, 1996-2030 = 1,450 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	7,780	-31	7,749	0.06%
2000	52,285	-266	52,019	0.58%
2005	95,080	-516	94,563	1.09%
2010	123,442	-720	122,723	1.46%
2015	112,716	-751	111,965	1.47%
2020	97,191	-736	96,455	1.44%
2025	80,072	-720	79,352	1.37%
2030	57,642	-798	56,844	1.18%

Cumulative SO2 reduction, 1996-2030 = 2,985,814 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	%U.S. NOx Power Plant Emissions
1996	4,884	-55	4,829	0.06%
2000	38,923	-567	38,356	0.57%
2005	76,501	-1,144	75,357	1.08%
2010	107,277	-1,653	105,624	1.45%
2015	104,505	-1,787	102,718	1.47%
2020	97,191	-1,812	95,378	1.42%
2025	87,731	-1,837	85,894	1.36%
2030	70,852	-1,492	69,360	1.18%

Cumulative NOx reduction, 1996-2030 = 2,739,383 tons

Table 7.4
Reduction of Pollutants for Fluorescent Ballasts (Sensitivity Case) - Level One

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	1,089	-47	1,042	0.05%
2000	3,182	-138	3,044	0.12%
2005	6,024	-232	5,792	0.20%
2010	8,406	-312	8,094	0.25%
2015	8,953	-315	8,638	0.24%
2020	9,309	-315	8,994	0.23%
2025	9,504	-296	9,208	0.21%
2030	9,901	-253	9,648	0.20%

Cumulative CO2 reduction, 1996-2030 = 250 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	6,113	-16	6,097	0.05%
2000	11,427	-63	11,364	0.13%
2005	18,307	-94	18,213	0.21%
2010	21,934	-141	21,793	0.26%
2015	18,820	-125	18,695	0.25%
2020	15,734	-125	15,609	0.23%
2025	12,464	-110	12,355	0.21%
2030	9,892	-31	9,861	0.21%

Cumulative SO2 reduction, 1996-2030 = 536,129 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change (tons)	%U.S. NOx Power Plant Emissions
1996	3,837	-43	3,794	0.05%
2000	8,506	-126	8,381	0.13%
2005	14,730	-212	14,518	0.21%
2010	19,062	-284	18,777	0.26%
2015	17,449	-288	17,161	0.25%
2020	15,734	-288	15,446	0.23%
2025	13,656	-271	13,385	0.21%
2030	12,159	-239	11,921	0.20%

Cumulative NOx reduction, 1996-2030 = 483,517 tons

Table 7.5
Reduction of Pollutants for Fluorescent Ballasts (Sensitivity Case) - Level Two

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	1,287	-66	1,221	0.05%
2000	3,953	-169	3,785	0.15%
2005	7,384	-293	7,091	0.25%
2010	10,263	-390	9,874	0.31%
2015	10,997	-392	10,605	0.30%
2020	11,443	-378	11,064	0.28%
2025	11,712	-373	11,339	0.26%
2030	12,091	-331	11,761	0.24%

Cumulative CO2 reduction, 1996-2030 = 307 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	7,225	-31	7,193	0.06%
2000	14,197	-78	14,118	0.16%
2005	22,441	-125	22,316	0.26%
2010	26,780	-172	26,608	0.32%
2015	23,116	-157	22,960	0.30%
2020	19,340	-141	19,199	0.29%
2025	15,360	-141	15,219	0.26%
2030	12,080	-63	12,018	0.25%

Cumulative SO2 reduction, 1996-2030 = 657,463 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change (tons)	%U.S. NOx Power Plant Emissions
1996	4,535	-60	4,475	0.06%
2000	10,569	-153	10,415	0.16%
2005	18,056	-267	17,789	0.25%
2010	23,273	-355	22,918	0.31%
2015	21,432	-359	21,073	0.30%
2020	19,340	-347	18,993	0.28%
2025	16,829	-342	16,487	0.26%
2030	14,849	-309	14,539	0.25%

Cumulative NOx reduction, 1996-2030 = 593,047 tons

Table 7.6
Reduction of Pollutants for Fluorescent Ballasts (Sensitivity Case) - Level Three

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	1,485	-66	1,419	0.06%
2000	4,339	-185	4,154	0.17%
2005	8,162	-323	7,838	0.27%
2010	11,241	-426	10,815	0.34%
2015	12,067	-434	11,634	0.32%
2020	12,606	-420	12,187	0.31%
2025	12,960	-414	12,545	0.29%
2030	13,329	-372	12,957	0.27%

Cumulative CO2 reduction, 1996-2030 = 338 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	8,336	-31	8,305	0.06%
2000	15,582	-78	15,503	0.17%
2005	24,803	-141	24,663	0.28%
2010	29,330	-188	29,143	0.35%
2015	25,366	-172	25,194	0.33%
2020	21,307	-157	21,150	0.32%
2025	16,996	-157	16,840	0.29%
2030	13,317	-78	13,238	0.28%

Cumulative SO2 reduction, 1996-2030 = 723,969 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change (tons)	%U.S. NOx Power Plant Emissions
1996	5,233	-60	5,173	0.06%
2000	11,600	-169	11,431	0.17%
2005	19,957	-295	19,662	0.28%
2010	25,489	-388	25,102	0.34%
2015	23,518	-397	23,121	0.33%
2020	21,307	-385	20,921	0.31%
2025	18,622	-380	18,242	0.29%
2030	16,368	-347	16,021	0.27%

Cumulative NOx reduction, 1996-2030 = 652,995 tons

APPENDIX A. MANUFACTURER COST DATA FOR FLUORESCENT BALLASTS

The following tables show the manufacturing costs (1990\$) for several design options for ten product classes of fluorescent lamp ballasts. The total incremental manufacturing cost is disaggregated into four subcategories: labor, materials and purchased parts, shipping/packaging, and tooling/equipment. The 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 costs for each design option is plus or minus 20%. The disaggregated costs for the ten product classes are based on cost estimates for the two-lamp F40 T12 lamp ballast.

Table A.1 1-Lamp F40T12 Ballast

Standard Level	Design	Labor	Materials*	Shipping/Packaging	Tooling	Total
0	Baseline	1.27	2.87	0.34	0.02	4.50
1	0+Cathode cutout	1.37	4.68	0.36	0.09	6.50
2	0+Electronic, RS	2.00	8.06	0.52	1.42	12.00

*Includes materials and parts.

Table A.2 2-Lamp F40T12 Ballast

Standard Level	Design	Labor	Materials*	Shipping/Packaging	Tooling	Total
0	Baseline	1.27	3.37	0.34	0.02	5.00
1	0+Cathode cutout	1.37	5.18	0.36	0.09	7.00
2	0+Electronic, RS	2.50	7.65	0.52	1.33	12.00

*Includes materials and parts.

Table A.3 3-Lamp F40T12 Ballast

Standard Level	Design	Labor	Materials*	Shipping/ Packaging	Tooling	Total
0	Baseline	2.54	6.24	0.68	0.04	9.50
1	0+Cathode cutout	2.74	9.86	0.72	0.18	13.50
2	0+Electronic, RS	3.08	13.00	0.52	1.40	18.00

*Includes materials and parts.

Table A.4 4-Lamp F40T12 Ballast

Standard Level	Design	Labor	Materials*	Shipping/ Packaging	Tooling	Total
0	Baseline	2.54	6.74	0.68	0.04	10.00
1	0+Cathode cutout	2.74	10.36	0.72	0.18	14.00
2	0+Electronic, RS	3.00	13.78	0.52	1.70	19.00

*Includes materials and parts.

Table A-5 2-Lamp F96T12 Ballast

Standard Level	Design	Labor	Materials*	Shipping/ Packaging	Tooling	Total
0	Baseline	1.37	6.67	0.34	0.02	8.40
1	0+ Electronic	1.47	11.92	0.36	1.25	15.00

*Includes materials and parts.

Table A.6 2-Lamp F96HOT12 Ballast

Standard Level	Design	Labor	Materials*	Shipping/ Packaging	Tooling	Total
0	Baseline	1.47	13.67	0.34	0.02	15.50
1	0+Electronic	1.57	16.62	0.36	.60	18.60

*Includes materials and parts.

Table A.7 1-Lamp F32T8 Ballast

Standard Level	Design	Labor	Materials *	Shipping/ Packaging	Tooling	Total
0	Baseline	1.27	2.87	0.34	0.02	4.50
1	0+Cathode cutout	1.37	4.68	0.36	0.09	6.50
2	0+Electronic, RS	2.00	8.06	0.52	1.42	12.00
3	0+Electronic, IS	2.00	8.06	0.52	1.42	12.00

*Includes materials and parts.

Table A.8 2-Lamp F32T8 Ballast

Standard Level	Design	Labor	Materials *	Shipping/ Packaging	Tooling	Total
0	Baseline	1.27	3.37	0.34	0.02	5.00
1	0+Cathode cutout	1.37	5.18	0.36	0.09	7.00
2	0+Electronic, RS	2.50	7.65	0.52	1.33	12.00
3	0+Electronic, IS	2.50	7.65	0.52	1.33	12.00

*Includes materials and parts.

Table A.9 3-Lamp F32T8 Ballast

Standard Level	Design	Labor	Materials *	Shipping/ Packaging	Tooling	Total
0	Baseline	2.54	6.24	0.68	0.04	9.50
1	0+Cathode cutout	2.74	9.86	0.72	0.18	13.50
2	0+Electronic, RS	3.68	13.00	0.52	1.80	19.00
3	0+Electronic, IS	3.68	13.00	0.52	1.80	19.00

*Includes materials and parts.

Table A.10 4-Lamp F32T8 Ballast

Standard Level	Design	Labor	Materials *	Shipping/ Packaging	Tooling	Total
0	Baseline	2.54	6.74	0.68	0.04	10.00
1	0+Cathode cutout	2.74	10.36	0.72	0.18	14.00
2	0+Electronic, RS	3.48	15.00	0.52	2.00	21.00
3	0+Electronic, IS	3.48	15.00	0.52	2.00	21.00

*Includes materials and parts.

APPENDIX B. FORECASTING COMMERCIAL ENERGY WITH EPRI COMMEND

COMMEND is a commercial end-use forecasting program supported by EPRI (Electric Power Research Institute). COMMEND forecasts energy use by end use and building type. The model covers eleven building types, ten end uses and three fuel types. Version 3.2 was used for this analysis (13).

Forecast fuel prices and floor space are exogenous inputs to COMMEND. COMMEND models fuel switching and selection of equipment based on life-cycle-cost criteria. Decision-makers are in four groups with different discount rates. Short-run price elasticities for utilization of energy services are included. Interactions between lighting and space-conditioning energy use are also handled within the model.

Representation of Technologies

In COMMEND, technology options are represented as a technology trade-off curve that shows the efficiency attainable for a given equipment cost. Technology trade-off curves are defined for at least one equipment market for each energy end use. See Figure B.1 for a sample technology trade-off curve. COMMEND defines only one curve for the lighting end use. For heating, however, separate trade-off curves are defined to model equipment markets for technologies using different fuel types. A trade-off curve for a particular building type is defined by the year, equipment cost level, average Energy Use Intensity (EUI kWh/sq ft-year), and an elasticity representing the cost-efficiency relationship.

Figure B.1 COMMEND Framework

Uses for Market Data

- Forecasting
- Demand-Side Planning
- Integrated Planning
- Marketing

BUILDINGS

Small Office
Large Office
Restaurant
Retail
Grocery
Warehouse
Schools
Colleges
Health
Lodging
Miscellaneous

END USES

Space Heat
Cooling
Ventilation
Water Heat
Cooking
Refrigeration
Lighting
Miscellaneous

FUELS

Electricity
Natural Gas
Fuel Oil

Several equipment components make up the lighting end use: lamps, ballasts, fixtures, and controls. With COMMEND's present structure, it is not possible to represent the actual technology options for lighting directly; instead, technology options have to be mapped onto the technology trade-off curves for the single lighting end use by analyses performed outside COMMEND. Lighting component spreadsheets are used to derive lighting power densities (watts/sq ft) for each building type based on the energy characteristics and penetrations of the different component technologies, and these densities are then converted to EUIs using building operating hours developed from EIA data (14).

Development of COMMEND Input

The basic relation modeled by COMMEND is that lighting energy use is the product of floor area (in square feet for a given end use) and energy use per unit area (in kilowatt-hours per square foot) for that end use, or EUI, summed over all building types.

The analysis integrated a variety of data: current market shares, recent usage trends for various lighting products, and the LBL engineering analysis wattages and costs. The results of this integration were used first to develop a base case set of lighting EUIs. These EUIs were then used to calibrate COMMEND and develop reference forecasts against which the net impacts of the standards were estimated. The base case lighting EUIs were then modified to reflect the impact of lighting equipment and building standards. The difference in forecasts between the base case and the standard is the net energy impact. Table B.1 shows the EUIs used as input to COMMEND.

Table B.1. Commercial Lighting EUIs (kWh/sq ft.-yr): Input to COMMEND

	1983 stock	1986 stock	1986 new	1995 stock	1995 new
Small Office	6.74	6.64	6.61	5.66	5.09
Large Office	5.21	5.13	5.11	4.36	3.91
Restaurant	7.01	6.92	6.90	5.73	5.35
Retail	5.72	5.62	5.60	4.73	4.31
Grocery	12.92	12.74	12.69	10.84	9.72
Warehouse	3.65	3.60	3.59	3.11	2.84
School	2.89	2.84	2.83	2.41	2.17
College	5.30	5.24	5.22	4.45	3.97
Health	6.50	6.41	6.38	5.42	4.86
Lodging	4.20	4.14	4.13	3.34	3.19
Miscellaneous	3.70	3.64	3.62	3.08	2.79

Turnover of Lighting Equipment

At present, only one lifetime may be specified for the lighting end use in the model even though lamps usually have to be replaced much more frequently than ballasts and fixtures. Discrete lighting component representation is expected to be a feature of COMMEND Version 4.0.

A lifetime of 15 years is used in this analysis. Fifteen years approximates the average lifetime of ballasts,⁶ and corresponds to the average fixture turnover rate in renovated buildings.

Annual Operating Hours

To represent hours per year that commercial sector lighting equipment is operating for each building type, building operating hours from NBECS 1986 are used (15).

Calibration

As a first step in the calibration process, comparisons between COMMEND inputs and NBECS 1986, EIA's *Annual Energy Outlook 1991* (AEO), and *State Energy Data Report Consumption, 1960-1989* (SEDR) data were made in order to verify default assumptions in the model. Although there are definition discrepancies in the building types used by COMMEND and NBECS, as well as a 10% disagreement over the commercial building stock total, EUIs for most building types and total consumption across segments correlate well.

The calibration for the lighting end use incorporated available data on the state of the market in 1986 and the predicted state in 1995. Trends in the characteristics of the lighting end-use trade-off curves were defined to capture ongoing incentive programs, existing energy regulations, and market equipment cost reductions that take the market from the 1986 state to the predicted 1995 state. To achieve this transformation, existing programs and regulations were assumed to reduce the cost of high-efficiency technology options by 30% initially, and by an additional 1% per year, for a total of 42% from 1983 to 1995. These assumptions are close to what is happening in the market in the form of cost reductions from utility rebate programs, which typically offer 3-4 cents/kWh saved to their participants. Figure B.2 shows the cost shift as it affects the technology trade-off curves for lighting.

Baseline Forecasts

As described in Chapter 2 of this volume, three different baselines, *No Programs*, *Base Case*, and *High-Efficiency*, are used to gauge the impacts of policy actions. In all three baselines, trade-off curves for all end uses other than lighting remain stationary. For the *No Programs* baseline, the technology trade-off curve for the lighting end use is also held stationary at its 1983 level throughout the forecast period.

⁶15 years = ballast rated lifetime/fluorescent lighting annual operating hours.

For the *High-Efficiency* baseline, the 42% cost reduction (because of DSM programs, etc.) in the efficient end of the lighting technology trade-off curve is left in place after 1995 and the trade-off curve remains in its 1995 state. For the *Base Case* baseline, most of the price reduction at the efficient end of the trade-off curve (30 of the 42%) is removed after 1995 to model a case in which utilities no longer provide DSM incentives. The remaining cost reductions are left in place in order to simulate the permanent price effect that DSM programs and other market forces will have on the market for efficient technologies. In addition, the *Base Case* baseline includes small savings from state building codes that are introduced before 1995 and are expected to persist.

Figure B.2 1986 Commercial Energy Sales by End Use (1% of U.S. Total)

These three baseline forecasts provide a framework for analyzing a broad spectrum of future market scenarios. When the *No Programs* forecast is compared to the other two baselines, the effect of utility demand-side programs plus existing regulations and market forces can be estimated. The two other cases represent two bounds of the forecast range. The *High-Efficiency* baseline extends the 1995 market forecast to 2030, based on utility DSM programs, the EPA Green Lights Program, the Federal Energy Management Program (FEMP) relighting program, and existing lighting regulations. This case represents an aggressive level of incentives, but not a "maximum efficiency" scenario. The *Base Case* baseline accounts for the currently widespread DSM activity, but assumes that these programs do not persist at their current high level.

COMMEND uses an average consumer discount rate of 28% to model commercial consumer decision-making.

Table B.2 shows comparisons of the baselines with the 1991 AEO reference case (16).

Representation of Policies

Component efficiency standards are modeled by limiting the choice of decision-makers at the low-efficiency end of the lighting technology trade-off curve as shown.

Table B.2: Baseline Forecast Comparison, Commercial Sector (SITE Quads)

AEO '91 Reference Case	1990	1995	2000	2005	2010
Lighting	1.12	1.23	1.34	1.46	1.58
Electricity	2.85	3.20	3.56	3.98	4.46
Natural Gas	2.65	2.85	2.93	2.97	2.98
Fuel Oil (distillate + residual)	0.81	0.74	0.67	0.60	0.55
Total (does not include minor fuels)	6.31	6.79	7.16	7.55	7.99
No Programs Case					
Lighting	1.11	1.22	1.37	1.51	1.66
Electricity	3.22	3.63	4.15	4.67	5.24
Natural Gas	2.68	2.77	2.87	2.92	2.97
Fuel Oil (distillate + residual)	0.37	0.35	0.32	0.30	0.28
Total (does not include minor fuels)	6.27	6.75	7.34	7.89	8.49
Base Case					
Lighting	0.99	1.01	1.13	1.32	1.51
Electricity	3.10	3.42	3.91	4.48	5.10
Natural Gas	2.70	2.81	2.91	2.95	2.99
Fuel Oil (distillate + residual)	0.38	0.35	0.33	0.31	0.28
Total (does not include minor fuels)	6.18	6.58	7.15	7.74	8.38
Sensitivity Baseline (High Efficiency)					
Lighting	0.99	1.01	1.05	1.14	1.24
Electricity	3.10	3.42	3.83	4.30	4.83
Natural Gas	2.70	2.81	2.92	2.98	3.03
Fuel Oil (distillate + residual)	0.38	0.35	0.33	0.31	0.29
Total (does not include minor fuels)	6.18	6.58	7.09	7.59	8.16

APPENDIX C. LBL MANUFACTURER IMPACT MODEL FLUORESCENT LAMP BALLASTS

C.1 INTRODUCTION

The Lawrence Berkeley Laboratory Manufacturer Impact Model (LBL-MIM) collects all the calculations necessary to determine the impact of a change in appliance efficiency standards on an industry's profitability and scale of operation into one spreadsheet. Volume A, Appendix C, provides an overview and description of the LBL-MIM. There is a description of the economic theory and a discussion of each of the model's modules. In this appendix, the LBL-MIM input data and model runs for the fluorescent lamp ballast analysis are described together.

C.1.1 Engineering Cost Data

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

1. The incremental unit variable cost incurred by the manufacturer for each design option such as raw materials, direct labor, purchased parts, and increased transportation costs that increases the efficiency of the appliance. The incremental variable cost is listed for each design option for each product class.
2. The annual unit energy consumption (UEC) associated with each design option for each product class.
3. 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 as one figure for each design option requiring capital expenditures; the single figure covers all of the product classes.

The engineering input data are also listed for each standards level being analyzed (a 1990 calibration case, a 1996 base case using the 1990 standards, and standard levels 1, 2, 3, etc. 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 standards levels instead. The engineering data used as inputs to the LBL-MIM 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. For a thorough description of the collection and meaning of the engineering data, see the Engineering Analysis.

C.1.2 Industry Market Data

Industry Shipments

These data include annual industry shipments for the 1990 calibration case, the 1996 base case (using the 1990 standards), and the 1996 shipments for each of the standards levels. The 1990 shipments figure is based on a study by the Lighting Research Institute (17) and U.S. Census data.

Elasticities

Price and operating cost elasticities determine the effect on shipments of changes in appliance prices and operating costs. For fluorescent lamp ballasts, the price elasticity is estimated to be -0.08. The consumer discount rate of 25% then gives an operating cost elasticity of -1.11. The source of these elasticities is COMMEND, which includes data from NBECS 1986 (18), U.S. Census data, discussions with consultants, and from Pacific Northwest Laboratory (PNL). Because these elasticities are very important, a sensitivity analysis using different elasticities is done.

Product Class Market Share

Each of the product classes has a share of the total fluorescent lamp ballast market and the market share, or unit sales, for each product class is an input to the model. For fluorescent lamp ballasts, the market shares range from 0.05% for 4F32 watt lamps to over 50% of market for 2F40 lamps. Sources for these data include COMMEND, which includes data from NBECS 1986, U.S. Census data, discussions with consultants, PNL, and the Lighting Research Institute.

Markups

Manufacturers charge different markups over variable cost for different product classes, resulting in different profit margins for different product classes. For fluorescent lamp ballasts, the estimated markups for all product classes vary between 1.19 and 2.0.

Initial prices

The 1990 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 the Engineering and Manufacturer Analysis teams.

Energy price

This figure is the ratio of the price of a 1990 kWh to a 1996 kWh. The source is the LBL-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 fluorescent lamp ballasts are summarized in Tables C.1 to C.4. The expenditure schedule lists the costs incurred over time for preparations to meet the new standards. A percentage of the total cost is attributed to each year before the standards go into effect since that is when these expenses will be incurred.

Table C.1 Rates of Financial Costs

Variable	Value	Source
After-tax equity cost of capital ¹	6.9%	MIM calc. from public financial data ²
Interest rate on debt ¹	2.5%	MIM calc. from public financial data
Interest lost in cash ¹	1.0%	MIM calc. from public financial data
Rate of depreciation	17.7%	Public financial data
Tax rate	34.0%	Tax law

¹Cost of capital and interest rate are real rather than nominal

²Public financial data are from sources such as Value Line, Standard and Poor's, Moody's, individual company annual reports, and economic reports.

Table C.2 Other Financial Inputs

Variable	Value	Source
Cash	0.4%	Public financial data
Inventory and receivables	39.3%	Public financial data
Net depreciable assets	19.5%	Public financial data
General and administrative expenses	15%	Public financial data
Engineering expense	1.2%	Public financial data and industry sources ¹

¹Industry sources include consultants under contract to LBL and discussions with industry representatives.

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

Variable	Value	Source
Fixed part of all costs and depr. assets	10.1%	Industry sources
Fixed part of one-time capital costs	11.3%	Industry sources
Economic profit	5.9%	MIM est. from financial data
Debt/equity ratio	7.1	Public financial data
Markup on typical model	1.2	Industry sources
Ratio of highest to lowest markup	1.1	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	8 years	MIM calculation
Percent additional 1-X capital	50%	MIM estimate
Age of replaced capital	6 years	Public financial data

C.2 LBL-MIM INPUTS AND OUTPUTS SHOWING THE PRIMARY SCENARIO

Table C.5 Fluorescent Lamp Ballasts Version of LBL-MIM

Abbreviation	Full Name
1F40	1 Lamp @ 40 watts
2F40	2 Lamps @ 40 watts
2F96	2 Lamps @ 96 watts
2F96HO	2 Lamps @ 96 watts: High Output
3F40	3 Lamps @ 40 watts
4F40	4 Lamps @ 40 watts
1F32	1 Lamp @ 32 watts
2F32	2 Lamps @ 32 watts
3F32	3 Lamps @ 32 watts
4F32	4 Lamps @ 32 watts

Table C.6 Fluorescent Lamp Ballasts Version of LBL-MIM*Control Panel*

FLUORESCENT LAMP BALLASTS		Scenario: Primary		Standard Level = 1	
CONTROL FACTORS		Input Value	Cntrl	Vari- ation	Progrm Value Name
Price Elasticity		-0.080	0.00	30%	-0.080 IPE
Consumer Discount Rate		25.00%	0.00	30%	25.00% RD
Equity Cost of Capital		0.090	0.00	10%	0.090 ECC
Economic Profit		0.059	0.00	1%	0.059 EP
L-R Fixed Part of Costs & Assets		0.101	0.00	50%	0.101 FCA
L-R Fixed Part of 1-X Cap. Cost		0.113	0.00	60%	0.113 FIX
One-Time Capital Costs		0.181	0.00	20%	0.181 CC.N
Unit Variable Cost Increase		\$6.12	0.00	30%	6.120 dVC.N
Elasticity Curve Parameter		0.000	0.00	10%	0.000 ro.N
Short-Run Price Response to Demand		0.034	0.00	353%	0.034 SRPR
SUMMARY	NAECA	NEW	PRVIOUS		NEW
	BASE	L-RUN	CHANGE	CHANGE	S-RUN
Shipments	13.03	13.86	6.30%	6.30%	13.84
Price	\$11.06	\$13.83	25.03%	25.03%	\$13.90
Revenue (in \$M)	144.18	191.62	32.91%	32.91%	192.42
Net Income	1.15	1.26	0.11	0.11	1.86
ROE	15.53%	16.03%	0.51%	0.51%	23.67%
Trys =				2.00	

Table C.7 Fluorescent Lamp Ballasts Version of LBL-MIM

The Monte Carlo Module

MONTE CARLO DETERMINATION OF STANDARD ERRORS OF ESTIMATES						
			Secnds/iteration =	2.97	time	
			Iterations to go =	0.00	nn	
FLUORESCENT LAMP BALLASTS			Sample Size =	400.00		
	%dQ	%dP	%dR	%dNI	dROE.N	dROE.S
Value	6.30%	25.03%	32.91%	11.02%	0.51%	8.14%
Means	31.14%	31.35%	70.74%	973.00%	4.96%	76.61%
Std. Dev	93.63%	18.70%	118.05%	8120.34%	10.50%	194.96%
History	0.05	0.28	0.34	-0.16	-0.03	0.38
...	1.71	0.66	3.51	46.59	0.20	3.63
Range	0.17	0.24	0.46	1.05	0.08	2.06
Name	0.26	0.26	0.59	0.75	0.03	1.86
Is	0.43	0.18	0.70	9.52	0.51	3.08
Carlo	0.63	0.73	1.82	8.56	0.23	0.43
	0.06	0.26	0.34	-0.10	-0.02	0.50
	-0.03	0.47	0.43	0.03	0.01	0.01
	-0.03	0.82	0.78	-0.20	-0.02	1.03
	0.21	0.49	0.80	2.31	0.16	13.24
	0.13	0.26	0.42	0.30	0.02	0.62
	0.23	0.20	0.47	0.86	0.05	0.12
	0.73	0.18	1.04	5.38	0.12	4.70
	2.24	0.21	2.92	27.44	0.08	8.86
	0.07	0.37	0.47	0.17	0.01	0.05
	0.93	0.32	1.55	5.59	0.08	1.22
	0.06	0.25	0.33	0.01	-0.01	0.36
	0.10	0.01	0.11	0.06	0.00	0.00
	0.18	0.11	0.31	1.02	0.08	0.21
	8.44	0.05	8.87	260.28	-0.04	2.99
	0.10	0.36	0.50	0.34	0.03	0.10
	0.01	0.21	0.23	-0.16	-0.02	-0.03
	0.29	0.20	0.54	1.90	0.11	1.43
	0.10	0.56	0.73	0.33	0.02	1.89

Table C.8 Fluorescent Lamp Ballasts Version of LBL-MIM*The Accounting Module*

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

	1990	BASE '96	NEW '96	CHANGE
Revenue	94.42	144.18	191.62	32.9%
Expenses				
Cost of Goods Sold	78.66	127.86	174.82	36.7%
Selling & G & A	7.35	7.48	7.60	1.6%
Engineering	0.59	0.60	0.61	1.6%
Depreciation	3.34	3.34	3.34	NA
1-X Depreciation	0.00	0.01	0.02	NA
Total Expenses	89.94	139.30	186.39	33.8%
Earnings Before Interest & Taxes	4.48	4.88	5.24	7.3%
Interest	2.93	3.14	3.33	6.0%
Earnings Before Taxes	1.55	1.74	1.90	9.6%
Taxes	0.53	0.59	0.65	10.0%
Net Income	1.02	1.14	1.25	9.4%
Gross Margin	16.69%	11.32%	8.77%	-22.49%
Return on Sales	1.08%	0.79%	0.65%	-17.7%
Total Assets	55.88	60.04	63.73	6.1%
Return on Assets (w/intrst taxed)	5.29%	5.36%	5.41%	0.1
Equity	6.88	7.39	7.85	6.1%
Return on Equity	14.85%	15.47%	15.94%	0.5

ECONOMIC ANALYSIS

	1990	BASE '96	NEW '96	CHANGE
Shipments	12.11	13.03	13.86	6.3%
Price	\$7.80	\$11.06	\$13.83	25.0%
Revenue	94.42	144.18	191.62	32.9%
EXPENSE (W/ INTEREST)				
Fixed Costs	9.57	9.57	9.57	0.0%
Variable Costs (w/ Q)	83.30	132.86	132.61	-0.2%
Total Expenses	92.87	142.43	142.18	-0.2%
ASSETS				
Cash	0.37	0.40	0.43	6.3%
Inventories	37.11	39.95	42.47	6.3%
Depreciable	18.39	19.68	20.83	5.8%
Total Assets	55.88	60.04	63.73	6.1%

Table C.9 Fluorescent Lamp Ballasts Version of LBL-MIM

The Engineering Inputs Module

		Increment in Additional UVC by Level and Class			
Baseline		0	0+EFF.CUT	0+RAPID.EE	0+INST.EE
	1F40	4.5	1.9	6.1	
	2F40	5	1.9	5.7	
	2F96	8.4	0.0	5.4	
	2F96HO	15.5	0.0	2.5	
	3F40	9.5	3.8	7.1	
	4F40	10	3.8	7.3	
	1F32	4.5	1.9	6.1	6.1
	2F32	5	1.9	5.7	5.7
	3F32	9.5	3.8	7.7	7.7
	4F32	10	3.8	9.0	9.0
VCS.E		Additional UVC. (Above Level 0 cost.)			
	CLS	0	1	2	3
	0	0	2	6	0
	1	0	2	6	0
	2	0	0	5	0
	3	0	0	3	0
	4	0	4	7	0
	5	0	4	7	0
	6	0	2	6	6
	7	0	2	6	6
	8	0	4	8	8
	9	0	4	9	9
KWH.PRINT		Kw Hrs /Yr			
		0	1	2	3
	1F40	141	135	114	
	2F40	261	249	222	
	2F96	474	0	396	
	2F96HO	711	0	570	
	3F40	402	384	327	
	4F40	522	498	424	
	1F32	111	105	96	90
	2F32	222	210	192	180
	3F32	333	315	285	267
	4F32	444	420	396	372

Table C.9 Fluorescent Lamp Ballasts Version of MIM (continued)
The Engineering Inputs Module

	KWS.E0	0	1	2	3
	1F40	11	10	9	0
	2F40	20	19	17	0
	2F96	36	0	30	0
	2F96HO	54	0	44	0
	3F40	31	29	25	0
	4F40	40	38	32	0
	1F32	8	8	7	7
	2F32	17	16	15	14
	3F32	25	24	22	20
	4F32	34	32	30	28
	Capital cost / unit / 7	0	1	2	3
	1F40	4.5	0.1	1.4	
	2F40	5	0.1	1.3	
	2F96	8.4	0.0	1.3	
	2F96HO	15.5	0.0	0.6	
	3F40	9.5	0.2	1.4	
	4F40	10	0.2	1.7	
	1F32	4.5	0.1	1.4	1.4
	2F32	5	0.1	1.3	1.3
	3F32	9.5	0.2	1.8	1.8
	4F32	10	0.2	2.0	2.0
CC.E	Additional CC. (Above Level 0 cost.)				
	CLS	0	1	2	3
	0	0	0.1	1.4	0
	1	0	0.1	1.3	0
	2	0	0.0	1.3	0
	3	0	0.0	0.6	0
	4	0	0.2	1.4	0
	5	0	0.2	1.7	0
	6	0	0.1	1.4	1.4
	7	0	0.1	1.3	1.3
	8	0	0.2	1.8	1.8
	9	0	0.2	2.0	2.0
	Additional CC. * 7	0	1	2	3
	1F40	0.0	0.6	10.2	0
	2F40	0.0	3.9	57.6	0
	2F96	0.0	0.0	15.6	0
	2F96HO	0.0	0.0	4.3	0
	3F40	0.0	1.3	10.1	0
	4F40	0.0	1.3	12.2	0
	1F32	0.0	0.0	0.0	0.0
	2F32	0.0	7.6	112.7	112.7
	3F32	0.0	0.0	0.0	0.0
	4F32	0.0	0.0	0.0	0.0
	CCEE.E	0	15	223	113

Table C.10 Fluorescent Lamp Ballasts Version of LBL-MIM

The Standards Level Module

LevIn prev	LEV.B	lev.N	Eng:	0 ...	7	"Emax
-1	0	1	REM:	-1 ...	8	"Smax
1	1	1		1 ==> Sundrds	0 ==> Eng.	
SIE	SIE.B	SIE.N	Esc = QUTT			

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

LEVEL -->	-1=1990	0=1996	1	2	3
1F40	0.04	0.76	3.46	6.08	6.08
2F40	0.04	0.72	3.31	5.67	5.67
2F96	0.04	1.27	5.35	5.35	5.35
2F96HO	0.00	0.60	2.50	2.50	2.50
3F40	0.05	1.10	5.04	7.10	7.10
4F40	0.05	1.12	5.12	7.30	7.30
1F32	0.00	4.44	5.85	6.08	6.08
2F32	0.00	4.15	5.46	5.67	5.67
3F32	0.00	5.68	7.49	7.70	7.70
4F32	0.00	6.62	8.71	9.00	9.00

KWS.R Kw Hrs /Yr

LEVEL -->	-1=1990	0=1996	1	2	3
1F40	10.77	10.55	9.73	8.72	8.72
2F40	19.94	19.60	18.28	16.98	16.98
2F96	36.22	34.84	30.29	30.29	30.29
2F96HO	54.39	51.82	43.61	43.61	43.61
3F40	30.71	30.10	27.75	25.02	25.02
4F40	39.88	39.07	35.99	32.44	32.44
1F32	8.49	7.33	6.96	6.90	6.89
2F32	16.98	14.66	13.93	13.80	13.77
3F32	25.47	21.83	20.67	20.47	20.43
4F32	33.97	29.98	28.72	28.52	28.46

CC.R

LEVEL -->	-1=1990	0=1996	1	2	3
1F40	0.01	0.13	0.59	1.42	1.42
2F40	0.01	0.12	0.55	1.33	1.33
2F96	0.01	0.30	1.25	1.25	1.25
2F96HO	0.00	0.14	0.60	0.60	0.60
3F40	0.01	0.14	0.63	1.40	1.40
4F40	0.01	0.16	0.75	1.70	1.70
1F32	0.00	1.02	1.35	1.42	1.42
2F32	0.00	0.96	1.26	21.33	1.33
3F32	0.00	1.30	1.71	1.80	1.80
4F32	0.00	1.44	1.90	2.00	2.00

Table C.10 Fluorescent Lamp Ballasts Version of LBL-MIM (continued)
The Standards Level Module

ADDITIONAL CC *7						
LEVEL -->	-1=1990	0=1996	1	2	3	
1F40	0.00	0.00	0.00	0.01	0.01	
2F40	0.00	0.01	0.03	0.06	0.06	
2F96	0.00	0.00	0.02	0.02	0.02	
2F96HO	0.00	0.00	0.00	0.00	0.00	
3F40	0.00	0.00	0.01	0.01	0.01	
4F40	0.00	0.00	0.01	0.01	0.01	
1F32	0.00	0.00	0.00	0.00	0.00	
2F32	0.00	0.09	0.12	0.12	0.12	
3F32	0.00	0.00	0.00	0.00	0.00	
4F32	0.00	0.00	0.00	0.00	0.00	
CCEE.R						
LEVEL -->	-1=1990	0=1996	1	2	3	
Cumltv CC	0	0	5	5	5	
	0.00	0.10	0.18	0.25	0.25	
	1990	1996	NEW96	1990	1996	NEW96
	VC87	VCB	VCN	KW87	KWB	KWN
1F40	0.04	0.76	3.46	10.77	10.55	9.73
2F40	0.04	0.72	3.31	19.94	19.60	18.28
2F96	0.04	1.27	5.35	36.22	34.84	30.29
2F96HO	0.00	0.60	2.50	54.39	51.82	43.61
3F40	0.05	1.10	5.04	30.71	30.10	27.75
4F40	0.05	1.12	5.12	39.88	39.07	35.99
1F32	0.00	4.44	5.85	8.49	7.33	6.96
2F32	0.00	4.15	5.46	16.98	14.66	13.93
3F32	0.00	5.68	7.49	25.47	21.83	20.67
4F32	0.00	6.62	8.71	33.97	29.98	28.72
	1990	1996	NEW96	Weighted	Base Case	New Sids
	CPC87	CPCB	CPCN	Op Cost	Weighted	Weighted
					d P	d P
1F40	0.01	0.13	0.59	0.92	0.02	0.04
2F40	0.01	0.12	0.55	10.18	0.07	0.08
2F96	0.01	0.30	1.25	5.33	0.21	0.70
2F96HO	0.00	0.14	0.60	4.62	0.04	0.14
3F40	0.01	0.14	0.63	2.61	0.03	0.06
4F40	0.01	0.16	0.75	3.39	0.03	0.07
1F32	0.00	1.02	1.35	0.01	0.53	0.97
2F32	0.00	0.96	1.26	0.01	0.91	1.39
3F32	0.00	1.30	1.71	0.01	0.68	1.24
4F32	0.00	1.44	1.90	0.02	0.79	1.44
	Wgt Fuel Cost: F			27.0929	3.31311	6.12036
					dVC.B0	dVC.N0
	---OUTPUT---					
	CC.87	CCB	CCN	CC.B0	CC.N0	dVC.B.CV
	0.00087	0.10404	0.18189	0.10317	0.18102	25.00%

Table C.11 Fluorescent Lamp Ballasts Version of LBL-MIM

The Costs, Sales, and Revenue Module

			bb	-115
			aa	620
Ratio of highest to lowest markup:	ratio.0	1.10	ratio.cv	0.20
Typical markup over UVC	mid.0	0.20	mid.cv	0.20
Size of firm as % of industry	size.0	0.23		

CALIBRATION CASE (1990)

	Indst	Relatv	----- Firm -----					
	Ship.	Ship.	Ship.	Price	Rev.			Weighted
		Q%	Q.1	P.1/Range	R.1	m.1	UVC.1	"UVC
1F40	4.47	0.09	1.03	4.90	5.04	1.19	4.11	0.35
2F40	26.88	0.51	6.18	5.45	33.66	1.19	4.56	2.33
2F96	7.75	0.15	1.78	9.15	16.30	1.20	7.62	1.12
2F96HO	4.47	0.08	1.03	16.88	17.35	1.21	13.92	1.18
3F40	4.47	0.09	1.03	10.35	10.65	1.20	8.61	0.73
4F40	4.47	0.09	1.03	10.89	11.21	1.20	9.05	0.77
1F32	0.04	0.00	0.01	4.90	0.05	1.19	4.11	0.00
2F32	0.03	0.00	0.01	5.45	0.03	1.19	4.56	0.00
3F32	0.03	0.00	0.01	10.35	0.06	1.20	8.61	0.00
4F32	0.03	0.00	0.01	10.89	0.07	1.20	9.05	0.00
TOTAL S	52.64	20.00%	12.11	\$8	94.42	1.20	20.00%	6.50
	"TS.0	"Q.CV	Q.0	P.0	R		"P.CV	UVC

BASE CASE (1996)

	Rule-of-	Rule-of-		Op Cost	Weightd		
	Thb d P	Thb Price		Pi.B	Ratio	OpCst-R	Qi.B
							Ri.B
1F40	0.98	1.91	0	\$5.82	0.98	0.02	0.3258
2F40	0.93	8.40	1	\$6.32	0.98	0.10	1.3164
2F96	1.79	23.94	7	\$10.74	0.96	0.16	2.1896
2F96HO	0.88	16.66	1	\$17.71	0.95	0.07	0.9384
3F40	1.40	3.83	1	\$11.62	0.98	0.02	0.3258
4F40	1.44	4.02	1	\$12.20	0.98	0.02	0.3258
1F32	6.39	17.65	64	\$8.79	0.86	0.10	1.5640
2F32	5.97	32.80	102	\$9.23	0.86	0.19	2.8726
3F32	8.22	29.04	106	\$14.42	0.86	0.10	1.5640
4F32	9.50	31.90	141	\$14.86	0.88	0.11	1.5640
	0.06	170.15	424	11.1	144.18	-0.09	13.0336
	Alpha.B	Sum P (2)	Sum (3)	"P.B	Sum(Ri)	OC%.B0	"Q.B
					check=R.B.		"R.B

Table C.11 Fluorescent Lamp Ballasts Version of LBL-MIM (continued)

The Costs, Sales and Revenue Module

NEW STANDARDS CASE (1996)								
	Rule-of- Thb d P	Rule-of- Thb Price		Pi.N	% Chng Op Cost	Weightd OpCst-R	Qi.N	Ri.N
1F40	4.69	1.66	4	\$8.7	0.90	0.01	17.32%	1.51
2F40	4.48	3.55	7	\$9.1	0.92	0.02	35.75%	3.26
2F96	7.69	30.66	108	\$14.5	0.84	0.11	182.07%	26.41
2F96HO	3.68	15.68	10	\$20.0	0.80	0.04	76.30%	15.28
3F40	6.66	2.95	8	\$15.3	0.90	0.01	17.32%	2.64
4F40	6.87	3.20	9	\$15.9	0.90	0.01	18.01%	2.86
1F32	8.41	30.42	162	\$10.5	0.82	0.14	228.61%	24.05
2F32	7.86	46.95	218	\$10.9	0.82	0.21	352.89%	38.36
3F32	10.82	48.39	268	\$16.6	0.81	0.13	228.61%	37.84
4F32	12.51	53.49	358	\$17.2	0.85	0.14	228.61%	39.40
TOTAL	0.04	236.95	1150	13.8	191.62	-0.17	13.8550	191.62
	Alpha.N	Sum P (2)	Sum (3)	"P.N	Sum(Ri)	OC%.N0	"Q.N	"R.N
check=R.N								

Market Share Distributions by Standards Levels.

Class	blevel						NS.Index
	Cal	Base	1	2	3		
1F40	8.50%	2.50%	1.25%	0.50%	0.00%	1.25%	
2F40	51.06%	10.10%	2.58%	1.22%	0.00%	2.58%	
2F96	14.72%	16.80%	13.14%	11.92%	11.03%	13.14%	
2F96HO	8.49%	7.20%	5.51%	4.99%	4.62%	5.51%	
3F40	8.50%	2.50%	1.25%	0.50%	0.00%	1.25%	
4F40	8.50%	2.50%	1.30%	0.50%	0.00%	1.30%	
1F32	0.08%	12.00%	16.50%	17.50%	18.50%	16.50%	
2F32	0.05%	22.04%	25.47%	27.86%	28.85%	25.47%	
3F32	0.05%	12.00%	16.50%	17.50%	18.50%	16.50%	
4F32	0.05%	12.00%	16.50%	17.50%	18.50%	16.50%	

Table C.12 Fluorescent Lamp Ballasts Version of LBL-MIM

The Financial Module

INPUT	NAME	VALUE	NAME	C.V. or Control Factor
RATES of COST				
After Tax Equity Cost of Capital	ECC.0	6.80%	ECC.CV	10%
Interest Rate on Debt	I.0	2.50%	LCV	100%
Interest Lost on Cash	ICash.0	1.00%	ICASH.CV	100%
Rate of Depreciation	Dep.0	17.70%		
Tax Rate	T.0	34.00%	T.CV	20%
ASSETS and COSTS as a PERCENT of REVENUE				
Cash	C:R.0	0%	C:R.CV	100.00%
Inventory & Receivables	IR:R.0	39%	IR:R.CV	27.19%
Depreciable Assets	DA:R.0	19%	DA:R.CV	36.89%
G & A	G&A.0	15%	G&A.CV	40.00%
Engineering	Eng	1.20%		
FIXED AND VARIABLE COST SPLIT				
Fixed Part of All Costs & Depr Assets	FDA.0	10.14%	FCA.CV	50.00%
Fixed Part of 1-X Capital Cost	FIX.0	11.28%	FIX.CV	60.00%
OTHER				
Economic Profit	EP.0	5.85%	EP.CV	1.00%
Debt to Equity ratio	DER.0	712.00%	DER.CV	43.36%
Markup on typical model	"mid	20.00%		
Ratio of highest to lowest markup	"ratio	110.00%		
OUTPUT				
Depreciation	DRR	3.5%		
G&A to Overhead Ratio	G:O	92.6%		
Engineering to Overhead Ratio	E:O	7.4%		
Debt Ratio	DR	87.7%		
Equity Ratio	ER	12.3%		
Pre-Tax Equity Cost of Capital*	PECC	13.6%		
Weighted Average Cost of Capital	WACC	6.9%		
After-Tax WACC	ATWACC	4.6%		
Return on Equity	ROE	0.149		
Input ROE (Real)	ROE.0	14.85%		

All interest rates and costs of capital are "real".

*When Pre-Tax ECC is used, all costs are counted tax-exempt.

Table C.13 Fluorescent Lamp Ballasts Version of LBL-MIM

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%	

COMPUTATION

DESCRIPTION	NAME	VALUE	
Continuous After-Tax WACC	ATR	4.48%	
Weighted CC Lead-Time Factors	0.00	0.28	0.53 0.26
Cumulative CC Lead-Time Factors	LTC.0	1.074	
$\exp(-ATR*TL)$	EMRT	0.764	
$\exp(-ATR*L)$	EMRL	0.699	
Rate of tax benefit	3.30	BN	0.057
Remaining tax life	RTL	5.00	years
Tax Benefit Rate: $(1-\%NC)*BN$	BEN	0.028	
Discount factor: $@\exp(-ATR*(L-(TL-RTL)))$	DIS	0.73	
Loss of tax benefit on portion of existing capital with remaining tax life	LEC1	0.127	
Loss of tax benefit on discounted existing capital expenditure in the future	LEC2	0.109	
LEVELIZED CC		GROSS CC	TAX EFF
Initial Cost		1.000	
Tax Benefit of Straight-Line Depreciation			0.298
Savings from not replacing existing Capital later		-0.365	
Loss of Tax Benefit from existing Capital			-0.236
Present Value of CC:		0.635	0.062
Adjusted for Capital Lead Time		0.682	0.067
Levelized Tax Benefit: 1-X dep. of existing Cap.			0.003
LEVELIZED CC FACTOR	CCLF	0.101	0.013
AVERAGE ASSET FACTOR			
Asset Factor for Any New Cap. or Asset	AFB	0.559	
Average Asset Factor for Add-on Capital	AAF	0.280	

INPUT

NEW CAP. COST: 1990-96 (\$000)	CC.B0	0.10
1996 CHANGE	CC.N	0.18
COEFFICIENTS OF VARIATION	CCL.CV	0.20

OUTPUT

	BASE CASE 1996	NEW STNDS 1996	
Levelized 1-X CC: Gross	LCC.B	0.01	LCC.N 0.02
Levelized 1-X CC: Tax Effects	LCC.TB	0.00	LCC.TN 0.00
Levelized 1-X CC: Net	LCC.NB	0.01	LCC.NN 0.02
Levelized 1-X Assets	LA.B	0.03	LA.N 0.05

Table C.14 Fluorescent Lamp Ballasts Version of LBL-MIM

The Long-Run Model Module

1990 CASE			A.F	A.Q	A:R	A
Assets	-->		0.020	0.572	0.592	56
Costs except taxes			TC.F	TC.Q	TC:R	TC
and equity -->			0.101	0.882	0.984	93
			EC.F	EC.Q	EC:R	EC
Economic costs	-->		0.067	0.589	0.996	94
		Economic Income			EI:R	0.0043
		Markup (mu - 1)			mu1	0.1213
		Price Leader's elasticity of demand:				-9.2
BASE 1996			A.BF	A.BQ		A.B
Assets			1.86	4.46		60.04
			TC.BF	TC.BQ		TC.B
Costs except taxes			9.57	10.19		142
			EC.BF	EC.BQ		EC.B
Economic costs			6.34	6.78		127
NEW 1996			A.NF	A.NQ		A.N
Assets			1.86	4.46		63.73
			TC.NF	TC.NQ		TC.N
Costs except taxes			9.57	13.00		190
			EC.NF	EC.NQ		EC.N
Economic costs			6.34	8.63		158
Assets	-----1990-----		---BASE 1996---		----NEW 1996----	
Shipments	"Q	12.11	Q.B	13.03	Q.N	13.86
Price	"P	\$7.80	P.B	\$11.06	P.N	\$13.83
Revenue	"R	94.42	R.B	144.18	R.N	191.62
Unit Var. Cost	"UVC	\$6.50	UVC.B	\$9.81	UVC.N	\$12.62
V. Cost Goods Sold	VCGS	78.66	VCGS.B	127.86	VCGS.N	174.82
1X tax benefit			X1T.B	0.00	X1T.N	0.00
Pre-tax cost	PTC	92.87	PTC.B	142.44	PTC.N	189.71
Taxes	TAX	0.53	TAX.B	0.59	TAX.N	0.65
Net Income	NI	1.02	NI.B	1.15	NI.N	1.26
Economic Income	EI	0.40	EI.B	0.48	ELN	0.55
Equity	EQ	6.88	EQ.B	7.39	EQ.N	7.85
Retm on Equity	"ROE	14.85%	ROE.B	15.53%	ROE.N	16.03%
ACCOUNTING PAGE CALCULATIONS						
	-----1990-----		---BASE 1996---		----NEW 1996----	
Interest not 1X	IC	2.93	IC.B	3.14	IC.N	3.33
Pre-intrst cst	PIC	89.94	PIC.B	139.30	PIC.N	186.39
1X depreciation			X1D.B	0.01	X1D.N	0.02
1X interest			X1I.B	0.00	X1I.N	0.00
1X equity cost			X1E.B	0.00	X1E.N	0.00

Table C.15 Fluorescent Lamp Ballasts Version of LBL-MIM

The Short-Run Model Module

Short-Run "Supply Elasticity of Price":			SRQE.0	0.034
$(Q/P) \cdot dP/dQ$				
Standard Error of SRQE			SRQE.SD	0.120
Random Value selected for this run:			"SRQE	0.034
R.S	192.42		"P.N	\$13.83
UVC.S	\$12.62		"Q.N	13.86
VCGS.S	174.69			
TC.S	189.56		ap	bp
TAX.S	0.97	P=a+bQ	13.36	0.04
PTC.S	189.59		0.94	cq
NLS	1.86	Q=c+dP	15.95	-0.15
A.S	63.73			
EQ.S	7.85		P.S	13.90
ROE.S	23.67%		Q.S	13.84
		Check P	\$13.86	
		Check Q		13.6325

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.16 Fluorescent Lamp Ballasts Version of LBL-MIM

The Charts Module

CHARTS OF SENSITIVITY AND PROFIT FOR FLUORESCENT LAMP BALLASTS

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

Scenario = Primary

Control Variables			Possible Standards Levels		
Name	Value	Changed	1	2	3
IPE	-0.080	-0.184	5.23%	5.96%	6.10%
RD	25.00%	57.48%	-1.15%	-1.35%	-1.40%
ECC	0.090	0.099	0.00%	0.00%	0.00%
EP	0.059	0.069	-0.05%	-0.05%	-0.05%
FCA	0.101	0.163	0.50%	0.58%	0.59%
FIX	0.113	0.196	-0.02%	-0.03%	-0.03%
CC.N	0.181	0.221	0.00%	0.01%	0.01%
dVC.N	6.120	8.209	-0.18%	-0.19%	-0.20%
ro.N	0.000	0.100	0.84%	0.96%	0.98%
SRPR	0.034	0.294	0.00	0.00	0.00

Change in Long-Run ROE from 1996 NAECA Base Case by Engineering and Standards Levels

Scenario = Primary

Level	Engin	Stndrds
1	4.72%	0.51%
2	1.89%	0.58%
3	3.22%	0.59%
4		

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CHAPTER 1. ENGINEERING ANALYSIS

1.1 INTRODUCTION

Televisions receive transmitted modulated radio-frequency signals, which they demodulate to produce visual images and sound. The display device for most television sets is a cathode ray tube, which is an evacuated tube containing an electron gun that creates a focused beam of electrons and a phosphor screen that emits light when excited by the electron beam. Energy is expended to amplify the signal, heat the filament, accelerate the electrons, and to control the position of the beam on the screen. Special features, such as electronic tuning and remote control, also consume energy. A recent interest in the industry is the effort to develop high-definition television (HDTV). Incorporation of this new technology to improve resolution would require changes in both manufacturing and broadcasting.

The calculation of annual energy consumption involves adding the annual operating and annual standby energy usage (1). Operating power is defined as the average of the white and black screen power demand, whereas standby power is the power drawn by the set with the power switch in the off position. The following equation defines the average annual energy consumption, E , in watt-hours:

$$E = P_o \times 2200h + P_s \times 6560h \quad (1)$$

where P_o equals the operating power and P_s equals the standby power, in watts. Sound energy does not affect test procedure measurements, as sound is not on during testing. Therefore, with the present test procedure, there is no need to separate classes according to stereo sound.

Manufacturing plant configuration varies considerably depending on the preference and business structure of each company. A flow diagram of the manufacturing process is shown in Figure 1.1. Some of the main components of televisions are printed circuit boards, cabinets, and picture tubes. Printed circuit board assembly is performed at locations that are usually outside the U.S. Small electronic components, such as resistors, transistors, and integrated circuits, are purchased from vendors. The assembly is typically highly automated. Picture tubes are either produced by the company or purchased from an outside source.

Figure 1.1 Manufacturing Flow Diagram for Television Sets

1.2 PRODUCT CLASSES

The two main types of televisions are black and white and color sets. Color televisions use more energy than black and white and offer an additional utility. Color receivers are more complex than monochrome sets because they must process additional information to produce color. Many color sets use a shadow mask color kinescope, in which color images are produced in the form of closely intermingled red, blue, and green dots. The primary color phosphor dots are excited by three separate electron beams, which are prevented from striking dots of the wrong color by the shadowing effect of the mask. Previous estimates have shown that for the same screen size, monochrome sets used approximately one-third the energy of color televisions (2). Monochrome sets sold today are usually portable or table models and more than 50% are designed for battery or battery-AC operation. The market share of black and white television sets is decreasing relative to color televisions; sales of color sets reached 21 million in 1990.

Screen size has an important impact on television energy use. Since a larger screen size offers a distinct utility for the consumer, any standards that might be established for televisions need to be a function of screen size. Table 1.1 lists the product classes for television sets. In 1989, 83% of color television sets sold to dealers reportedly included a remote control feature and virtually all television sets use electronic tuning (3).

Table 1.1 Product Classes for Television Sets

Black and white
Color, electronically tuned and remote-controlled

Monochrome sets are not analyzed because of their small and decreasing contribution to television energy consumption. As mentioned above, they use about one-third the energy of a similarly sized color set, and in 1986, they accounted for about 18% of all new television sales.

1.3 DESIGN OPTIONS FOR TELEVISION SETS

Improved energy efficiency is an indirect goal of all television manufacturers. In a highly competitive market, television design engineers try to improve the reliability of their products and to reduce the incidence of product or component failure. Since nearly all energy produced by the set ends up as heat inside the cabinet and this heat is the prime cause of component failure, energy efficiency increases reliability. Manufacturer costs can be reduced through the use of energy-efficient product design because reduced power requirements translate into smaller and less-expensive power supplies and dissipating resistors. Several design options to reduce energy use of television sets have been assessed. These are listed in Table 1.2.

Table 1.2 Design Options for Television Sets

Reduce standby power
More efficient power supply
More efficient display device

Reduce Standby Power

Television sets with remote control all have electronic tuning. Electronic tuning using frequency synthesis allows for receiving almost an unlimited number of channels. Mechanical tuning is quite limited in the number of available channels. Using electronic controls requires electronic memory to "remember" the control settings when the set is turned off. Therefore, the electronic tuner must receive power even when the television is turned off. Without standby memory, the set will wake up with all the controls in the default setting. Test marketing of sets without memory was unsuccessful, according to manufacturers.

The design option considered here is the installation of a transformer between the power line input and the electronic tuner. With the exception of some of the larger, high-end sets, most sets bring power to the tuner through a resistance circuit. This design has the advantage of low cost but is inherently inefficient. Selection of a step-down transformer with an output voltage of approximately 10-12V, which closely matches the tuner requirements, would reduce the tuner standby power requirement. Standby power is generally in the range of 1.5 to 8W, resulting in 13 to 70 kWh of energy use annually.

More Efficient Power Supply

Power supply regulation and filtering account for a large percentage of the energy used by the receiver. Power supplies can be dissipative (dumping excess or unneeded power through power resistors) or switching (essentially blocking unwanted power with a high-series impedance). Changing the resistive regulated power for the main DC voltage to a switching type would reduce power demand by approximately 6W or annual energy use by 13 kWh.

More Efficient Display Device

Replacement of the standard cathode ray picture tube (CRT) has been considered for many years, but is unlikely to occur in the near future. Three types of low-power flat screens being developed are liquid crystal display (LCD), gas plasma displays, and electroluminescent displays. LCDs are perhaps the most promising new technology, but are used only in prototype and specialty television sets. Television sets using LCDs as large as 14 inches (diagonal) are available; however, the manufacturing costs associated with LCDs increase dramatically as screen size increases (4). Based on relative cost and performance, the CRT is expected to remain dominant for the foreseeable future.

1.4 MANUFACTURER COST AND ENERGY USE DATA

Energy Use Data

Screen size is an important determinant of television energy usage as can be seen from frequency plots of annual energy use for three screen sizes. Figures 1.2 through 1.4 represent a total of 54 electronically tuned color television sets with remote control. These data were provided by one manufacturer who performed the testing on all the sets. This sample contains models from at least 10 manufacturers but is not necessarily representative of all color sets manufactured in 1987. The variation of energy usage among models of similar size (all with remote control and electronic tuning) is consistent with that found in previous studies (5).

Table 1.3 summarizes the average white and black picture power, standby power, and annual energy consumption for the three screen sizes. The 25-27" television sets use 71% more energy than the 13/14" sets. Since the screen size of 25-27" sets is 1.93 times that of 13/14" sets, energy use is less than proportional to screen size.

Table 1.3 Baseline Color Television Data

Class	Power (W)			Energy Use (kWh)
	White	Black	Standby	
13/14"	69	48	4.9	161
19/20"	95	59	4.6	199
25-27"	130	83	6.4	276

The data in the above figures show the range in energy use for a small sample of color televisions that all have electronic tuning and remote control. There appears to be no significant correlation of energy use with any single identifiable feature other than screen size. For example, r^2 in the regression analysis of energy use and standby power is 0.27, and for anode power and energy use, it is 0.32.

Energy Use Versus Screen Size

The data in Table 1.3 can be used to calculate the dependence of energy use on screen size. This dependence can then be used to set maximum energy use standards that are a function of screen size. Comparing 25-27" to 13/14" sets, it was found that the ratio of average energy uses for these two screen sizes is 1.71, as compared to the ratio of screen sizes of 1.93. Therefore,

$$E_{26}/E_{13/14} = 0.89 \cdot D_{26}/D_{13/14} \quad (2)$$

13-14" Color TVs Electronically Tuned

Figure 1.2 Energy-Use Distribution for Electronically Tuned Color Televisions: 13/14"

19–20" Color TVs

Electronically Tuned

7 out of 25 sets have standby power ≤ 2.1 Watts

Figure 1.3 Energy-Use Distribution for Electronically Tuned Color Televisions: 19/20"

25-27" Color TVs Electronically Tuned

Figure 1.4 Energy-Use Distribution for Electronically Tuned Color Televisions: 25/27"

For 19/20" and 13/14" sets, a similar analysis resulted in:

$$E_{19/20}/E_{13/14} = 0.86 * D_{19/20}/D_{13/14} \quad (3)$$

For 26" and 19/20" sets, it was found that:

$$E_{26}/E_{19/20} = 0.96 * D_{26}/D_{19/20} \quad (4)$$

These data indicate that energy use is less than proportional to screen size.

Using data from one manufacturer for several individual 1990 television sets, it was found that:

$$E_{27}/E_{20} = 0.88 * D_{27}/D_{20} \quad (5)$$

$$E_{31/35}/E_{20} = 0.93 * D_{31/35}/D_{20} \quad (6)$$

This confirmed the results obtained from 1987 television sets – that energy use is less than proportional to screen size – and also expanded the range of screen sizes analyzed to 31-35".

Using average power demand and screen-size data from Table 1.3, linear and quadratic regressions were performed to determine the functional relationship between power demand and screen size. After the regressions were performed, the test procedure equation was used to compute energy use. It was found that, between 13" and 26", both functional forms provided very good fits ($r^2 = 0.99$). The equations obtained are shown below:

$$E = 39.8 + 8.47 * D \quad \text{Linear} \quad (7)$$

$$E = 117.9 + 0.214 * D^2 \quad \text{Quadratic} \quad (8)$$

where D is the screen size. When the two equations above are used to calculate energy use at a screen size of 33", it is found that the linear approach provides a better fit to the expected value obtained from the ratio for 31-35" to 20" sets (see Eq. 6). Therefore, the linear approach was used in the following analyses to obtain the energy use/screen-size equations for each standard level.

For baseline energy use, the linear equation (see Eq. 7) was used. For standards level 1, the reduction in standby energy use was used to calculate a new y-intercept. The reduction is equal to 21 kWh/yr. Therefore, the energy use/screen-size equation is the following for standards level 1:

$$E_1 = 18.8 + 8.47 * D \quad (9)$$

For standards level 2, a regression analysis was performed to obtain the new intercept and slope. It was desired to have the regression equation pass through the point (19.5", 170.6 kWh/yr). This point is obtained from Table 1.4. Other points at higher and lower screen sizes were obtained through use of the ratios (see Eqs. 2-4) for the average energy use. Other data are not available to determine the energy use/screen-size relationship at this more efficient standard level. The resulting regression equation for standards level 2 is the following:

$$E_2 = 26.7 + 7.88 * D \quad (10)$$

This equation was normalized (by multiplying by 0.95) to have it pass through the point at (19.5", 170.6 kWh/yr). The equation that results is:

$$E_2 = 25.3 + 7.45 * D \quad (11)$$

The latter equation (Eq. 11) is used to establish the relationship between energy use and screen size for standards level 2.

For standard level 3, it was desired to have the regression equation pass through the point (19.5", 138.5 kWh/yr). Other points at higher and lower screen size were obtained through use of the ratios (see Eqs. 2-4) for the average energy use. The resulting regression equation for standards level 3 is the following:

$$E_3 = 21.6 + 6.4 * D \quad (12)$$

This equation was normalized to have it pass through the point at (19.5", 138.5 kWh/yr). The normalization factor was determined to be 0.95. The equation that results is:

$$E_3 = 20.5 + 6.1 * D \quad (13)$$

The latter equation (Eq. 13) is used to establish the relationship between energy use and screen size for standards level 3.

1.5 COST-EFFICIENCY DATA

Table 1.4 summarizes the cost-efficiency data for 19/20" color television sets with remote control and electronic tuning. The baseline set is one that uses 205 kWh per year. It has a standby power of 4.4W and white and black screen power of 100 and 60W, respectively. The baseline manufacturer cost is \$174 (1990\$). Cost data were not obtained for other screen sizes. The incremental manufacturer costs are assumed to be independent of screen size.

Table 1.4 Cost-Efficiency Data For 19/20" Color Televisions

Standard Level	Design Option	Manufacturers Cost 1990\$	Energy Use kWh/yr
0	Baseline	174.00	205.0
1	0 + Reduced Standby	176.15	184.0
2	1 + Eff. Power Supply	177.65	170.6
3	2 + Eff. Design	184.25	138.5

Reduced Standby Power

The first design option analyzed is the reduction of standby power from 4.4W to 2W. This is accomplished by replacing a dropping resistor in the tuner power supply with a separate transformer. The step-down transformer has an output of about 10-12W and is placed between the line input and the electronic tuner. This results in a white/black screen power of 97.6/57.6W. The incremental manufacturer cost is \$2.15.

Efficient Power Supply

The second design option is added to the reduced standby power option. A resistive regulated power supply is replaced by a switching type of power supply. This reduces the white/black screen power by 6W at an incremental manufacturer cost of \$1.50 (6).

Reduce White/Black Screen Power

This reduction in white/black screen power to 73/41W is based on the data obtained for the lowest energy user among the 19/20" television sets tested in 1987.¹ An incremental manufacturer cost of \$6.60, relative to the previous design, is assumed for this design option. There is a large uncertainty in this cost estimate. This reduction in power demand may be possible by redesigns such as reducing losses in deflection circuits and secondary power supplies.

1.6 MAXIMUM TECHNOLOGICALLY FEASIBLE DESIGNS

The maximum technologically feasible design is represented by the last entry in the cost-efficiency table (Table 1.4) and corresponds to an energy use of 138.5 kWh per year. It is based on limited 1987 data supplied by one manufacturer. Since it was not possible to obtain complete data on energy consumption of color television sets, it is not possible to be certain that 138.5 kWh is actually the lowest possible energy consumption for 19/20" sets with remote control and electronic tuning. Additionally, it is not known if a television similar to the one with the lowest energy consumption is still being manufactured. For other screen sizes, Eq. 13 can be used to determine the maximum technologically feasible design (or minimum energy use).

¹ Model #19LP56, manufactured by Sharp in 1987.

All of the energy-use values (and manufacturer costs as well) in Table 1.4 above have some uncertainty associated with them. For the maximum technologically feasible design (138.5 kWh/yr), the 95% confidence interval is estimated to range from 133 to 152 kWh/yr. That is, there is a 95% probability that the lowest energy-using 19/20" television set has an annual energy use between 133 and 152 kWh/yr. The higher value is the second-best television in the 1987 data set, and the lower value is the actual energy use of the most efficient television in that data set. The standby power for that most efficient television was 1.2 rather than 2.0W, as assumed for the minimum in this analysis.

CHAPTER 2. BASE CASE FORECASTS: TELEVISIONS

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

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, multifamily, 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 A, Chapter 5, of this Technical Support Document.

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. Average lifetimes are 11.5 years for color televisions and 6.5 years for monochrome televisions. The short lifetime of monochrome televisions is interpreted as reflecting early retirement and replacement with color televisions, rather than an indication of failure to function.

Table 2.1 Average Equipment Lifetime (Years) of Televisions

	Years	Source
Color TV	11.5	LBL
Mono TV	6.5	LBL

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 (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). The LBL-REM produces projections of annual energy consumption of new appliances after 1980. Table 2.2 shows the trends in efficiency and annual unit energy consumption.

The UEC of new units decreased 7% and 6%, respectively, for color and monochrome televisions from 1981 to 1990. Further decreases in UEC are projected to occur after the year 2000.

Table 2.2 Base Case Projection of Unit Energy Consumption for New Color Televisions

Year	UEC (kWh/year)	
	Color TV	Mono TV
1981	213.9	32.6
1990	199.0	30.6
1996	199.0	30.6
2000	199.0	30.6
2030	183.8	30.6

Source: LBL-REM.

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

Usage is assumed constant over time.

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 LBL-REM. LBL-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 of this volume.

The projection for the period 1981-1990 is calibrated to reasonable agreement with available data, including domestic shipments (from published trade association data) and surveys of appliance ownership (e.g., from DOE/EIA RECS (7) and the Bureau of the Census).

Annual installations of televisions are projected to increase from 20 million in 1990 to 28 million in 2030. Color televisions increase from nearly 18 million (1990) to 28 million (2030), but monochrome decline from 2.4 million (1990) to 0.04 million (2030). Tables 2.3 and 2.4 show the significant trends in the installation and saturation of this product.

The number of televisions per household is projected to increase from 1.9 in 1990 to 2.2 in 2030.

Table 2.3 Annual Installations of New Televisions in U.S. Households (Millions)

Year	Color TV	Mono TV	Total
1981	11.20	5.27	16.47
1990	17.77	2.43	20.19
1996	20.39	1.28	21.67
2000	22.36	0.85	23.21
2030	28.38	0.04	28.41

Table 2.4 Percent of Occupied U.S. Housing Units Having Televisions

Year	Color TV %	Mono TV %	Total %
1980	111	69	180
1990	167	26	193
1996	186	12	199
2000	194	8	202
2030	220	1	221

2.3.3 U.S. Residential Energy Consumption

U.S. residential energy consumption for this product is calculated each year as the product of the number of occupied households, the fraction of households owning the appliance, the average UEC (engineering estimate), and the usage behavior factor.

Table 2.5 shows the U.S. energy consumption, expressed in quadrillion Btu of primary energy using a conversion factor for electricity of one kWh per 11,500 Btu. Because of the replacement of monochrome by color sets and the increase in number of televisions owned, the energy consumption increases from 0.25 Quads in 1990 to 0.38 Quads in 2030.

Table 2.5 U.S. Residential Energy Consumption for Televisions
(Quadrillion Btu, Primary Energy)

Year	Color TV	Mono TV	Total
1981	0.15	0.02	0.17
1990	0.24	0.01	0.25
1996	0.28	0.00	0.28
2000	0.31	0.00	0.31
2030	0.38	0.00	0.38

2.3.4 Price of Purchased Appliances

Prices of new units increase slightly over time as energy-efficiency improvements are incorporated. Table 2.6 shows projected shipment-weighted average prices.

Table 2.6 Average Price of New Televisions in U.S. Households (1990 dollars)

Year	Color TV	Mono TV
1981	360	66
1990	361	68
1996	361	68
2000	361	68
2030	363	68

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 1992 to 2030, electricity prices are 3% lower while gas and distillate prices are 5% lower than those in the AEO 1991 forecast (8).
4. *Higher Energy Price.* Assume higher energy prices. Starting from 1992 to 2030, electricity prices are 3% higher while gas and distillate prices are 5% higher than those in the AEO 1991 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. Table 2.7 shows how the average price varies. Table 2.8 shows the differences in UEC 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 2.7 Average Purchase Price of New Color Televisions (1990 Dollars)

Year:	1981	1990	1996	2000	2030
Reference	360	361	361	361	363
1	342	342	346	346	346
2	378	379	379	379	379
3	360	361	361	361	363
4	360	361	361	361	366
5	360	361	365	368	379
6	360	361	363	363	366.

Table 2.8 Average Unit Consumption of New Color Televisions (kWh/Year)

Year:	1981	1990	1996	2000	2030
Reference	214	199	199	199	184
1	214	199	171	171	171
2	214	199	199	199	199
3	214	199	199	199	184
4	214	199	199	199	171
5	214	199	177	164	138
6	214	199	184	184	171.

CHAPTER 3. PROJECTED NATIONAL IMPACTS OF STANDARDS: TELEVISIONS

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

The principal outputs from the LBL-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 trial standards case.

These outputs are provided annually (or for selected years) and cumulatively over a period of time, i.e., 1996-2030. Energy savings are given for each year from implementation of standards to the end of the period. Net present value of the standards 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 trial standards 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. Section 3.5 presents net present value and Section 3.6 discusses the results of the sensitivity analyses.

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

3.1 STANDARDS LEVELS

Table 3.1 shows the correspondence between the trial standards levels, the engineering design levels, and the associated unit energy consumption.

Table 3.1 Trial Standards Levels for Televisions

	Trial Standard Level		
	1	2	3
Engineering design option:	1	2	3
Annual energy consumption (kWh)	183.8	170.6	138.5

3.2 ENERGY CONSUMPTION

Table 3.2 shows the past and projected average energy use of new televisions. The unit energy consumption of an average new color television is projected to remain the same for units bought from 1990 to 1996 in the absence of amended standards.

Table 3.2 Unit Energy Consumption for New Color Televisions (kWh/year)

Year	Base	Trial Standard Level		
		1	2	3
1981	214			
1990	199			
1996	199	184	171	139
2000	199	184	171	139
2015	184	184	171	139
2030	184	184	171	139

Source: LBL-REM.

Tables 3.3a to 3.3c present projections of total energy savings for (1) monochrome, (2) color, and (3) all televisions. Standards (affecting only color televisions) are projected to produce cumulative energy savings ranging from 0.52 Quads for standards level 1 to 3.13 Quads for standards level 3, during the period 1996-2030.

Table 3.3a U.S. Energy Consumption for Monochrome Televisions
(Quadrillion Btu, Primary)

Year	Base	Trial Standard Level		
		1	2	3
1981	0.022			
1990	0.009			
1996	0.004	0.004	0.004	0.004
2000	0.003	0.003	0.003	0.003
2015	0.001	0.001	0.001	0.001
2030	0.000	0.000	0.000	0.000
1996-2030	0.05	0.05	0.05	0.05
Cumulative Savings:		0.00	0.00	0.00
Percent of Base:		0.0%	0.0%	0.0%

Source: LBL-REM.

Table 3.3b U.S. Energy Consumption for Color Televisions (Quadrillion Btu, primary)

Year	Base	Trial Standard Level		
		1	2	3
1981	0.149			
1990	0.238			
1996	0.280	0.274	0.269	0.258
2000	0.306	0.290	0.276	0.245
2015	0.364	0.342	0.317	0.258
2030	0.384	0.384	0.356	0.290
1996-2030	12.18	11.66	10.90	9.05
Cumulative Savings:		0.52	1.28	3.13
Percent of Base:		4.3%	10.5%	25.6%

Source: LBL-REM.

Table 3.3c Total Annual Energy Consumption for Televisions (Quadrillion Btu, Primary)

Year	Base	Trial Standard Level		
		1	2	3
1981	0.171			
1990	0.247			
1996	0.284	0.278	0.273	0.262
2000	0.309	0.293	0.279	0.248
2015	0.365	0.343	0.318	0.259
2030	0.384	0.384	0.356	0.290
1996-2030	12.23	11.71	10.95	9.10
Cumulative Savings:		0.52	1.28	3.13
Percent of Base:		4.3%	10.5%	25.6%

Source: LBL-REM.

3.3 ANNUAL INSTALLATIONS

As shown in Table 3.4, installations² of televisions are assumed to be not affected by standards.

Table 3.4 Cumulative Installations of Televisions (Millions)

1996-2030	Base	Trial Standard Level		
		1	2	3
Mono	12	12	12	12
Color	868	868	868	868
Total	880	880	880	880
Change from Base				
Mono		0	0	0
Color		0	0	0
Total		0	0	0
Percent Change				
Mono		0.0%	0.0%	0.0%
Color		0.0%	0.0%	0.0%
Total		0.0%	0.0%	0.0%

Source: LBL-REM.

² 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.

3.4 APPLIANCE PRICES

Projections of the purchase prices for new color televisions in 1990 dollars are shown in Table 3.5. The prices will typically increase when standards come into effect in 1996 by \$2 (0.6%) at standards level 1, up to \$18 (5%) at standards level 3.

Table 3.5 Average Purchase Price for New Color Televisions (1990 Dollars Per Unit)

Year	Base	Trial Standard Level		
		1	2	3
1981	360			
1990	361			
1996	361	363	366	379
2000	361	363	366	379
2015	363	363	366	379
2030	363	363	366	379

Source: LBL-REM.

3.5 NET PRESENT VALUE (NPV)

The NPV for any product is calculated by first determining the difference in present value of unit life-cycle costs between the base case and standards case each year. That difference is then multiplied by the standards case shipments for the year. The NPV for the period (1996-2030) is the sum over the years of the annual values. A positive NPV of standards results when the new units in the standards case have lower present value of life-cycle cost than do new units in the base case. A negative NPV indicates higher costs with standards, relative to the base case.

Table 3.6 shows positive NPV (reduced costs) to society of \$1.2 billion (standard 1) to \$4.0 billion (standard 3). The ratio of benefits to costs ranges from 2.8 (standard 1) to 1.6 (standard 3).

Table 3.6 Net Present Value to Society of Standards for Color Televisions Purchased from 1996-2030 (1990 Billions Dollars, Discounted to 1990 at 7% Real)

	Trial Standard Level		
	1	2	3
BENEFIT (Energy)	1.08	2.36	5.49
COST (Equipment)	0.44	1.01	3.82
NET PRESENT VALUE = BENEFIT - COST	0.64	1.35	1.67
RATIO: BENEFIT/COST	2.5	2.3	1.4

Source: LBL-REM.

3.6 SENSITIVITY ANALYSIS

The base case and standards levels as described above constitute a reference case against which the impacts of standards under different assumptions may be compared. The sensitivity analysis is performed by running the LBL-REM for the base case and trial *standards level 3* for televisions. For each sensitivity case, the results for the trial standards level are compared to the corresponding base-case run and the differences are tabulated.

The assumptions in the sensitivity cases are described in Section 2.4 and listed in Table 3.7. Table 3.8 shows results for cumulative energy consumption. The sensitivity analysis of product shipments is given in Table 3.9. Table 3.10 shows the net present values. The first line of Tables 3.8 through 3.10 gives the results of the reference case (base case, standards level, and difference). The rest of the lines each give the results corresponding to one of the sensitivity cases, including the base case, standards case, and difference. Note that the changes in the impact of standards as a function of the changed assumptions (difference between the base and standards cases) are the principal results of the sensitivity analysis.

Table 3.7 Sensitivity Analysis Cases

Case	Description
1	Lower Equipment Prices
2	Higher Equipment Prices
3	Lower Energy Price
4	Higher Energy Price
5	High Equipment Efficiency
6	Market Discount Rates Decline

Table 3.8 Cumulative Energy Consumption of Color Television Sets During the Period 1996-2030 (Quadrillion Btu, Primary)

	Trial Standard		
	Base	Level 3	Difference
Reference	12.18	9.05	3.13
1	10.82	8.95	1.87
2	12.54	9.05	3.49
3	12.35	9.05	3.30
4	12.02	9.05	2.97
5	9.54	9.03	0.51
6	11.04	9.03	2.01

Table 3.9 Cumulative Shipments of Color Television Sets During the Period 1996-2030 (Millions)

	Trial Standard		Difference
	Base	Level 3	
Reference	868	868	0
1	868	868	0
2	868	868	0
3	868	868	0
4	868	868	0
5	868	868	0
6	868	868	0

Source: LBL-REM.

Table 3.10 Total Net Present Value to Consumers for Units Sold during the Period 1996-2030 (Discounted to 1990 at 4% Real)

Case	Net Present Value (Million \$)	
	Trial Standard	Level 3
Reference		4000
1		2326
2		3448
3		3968
4		3930
5		347
6		1613

Source: LBL-REM.

CHAPTER 4. LIFE-CYCLE COSTS AND PAYBACK PERIODS

The effect of standards on individual consumers includes a change in operating expense (usually decreased) and a change in purchase price (usually increased). The net effect is analyzed by calculating the life cycle cost (LCC), using the engineering data (Chapter 1) for energy consumption and equipment price, and assuming the energy price projected for 1996. Section 4.1 presents the LCC for each design option. The results are displayed as graphs and as tables of values. Sections 4.2 through 4.4 show the impacts of standards on consumers. Section 4.5 presents the effect of different assumptions on the life-cycle cost calculations.

The *difference* due to standards is calculated (Sections 4.2 to 4.4) 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 standards. Then only those appliance purchasers who are impacted by standards (i.e., those who would have chosen a design eliminated by standards) are included in calculating the impact of standards on consumers. The impact of standards is expressed by three measures:

- Section 4.2: Payback Period (PBP),
- Section 4.3: Change in Life-Cycle Cost (LCC), and
- Section 4.4: Cost of Conserved Energy (CCE).

4.1 LIFE-CYCLE COST FOR DESIGN OPTIONS

The LCC is the sum of the purchase price (PC) and the operating expense (OC) discounted over the lifetime (N) of the appliance.

$$LCC = PC + \sum_{t=1}^N \frac{OC_t}{(1 + r)^t} \quad (1)$$

If operating expenses are constant over time, Eq.1 simplifies to

where we have defined the Present Worth Factor:

$$LCC = PC + PWF \cdot OC \quad (2)$$

$$PWF = \sum_{t=1}^N \frac{1}{(1+r)^t} = \frac{1}{r} \left[1 - \frac{1}{(1+r)^N} \right] \quad (3)$$

The LCC is calculated for each class in the year standards are imposed, using a discount rate, r .

4.1.1 LCC Data Inputs

The purchase price is based on the factory costs in the Engineering Analysis (Chapter 1) and includes a factory markup plus distributor and retailer markups, calculated by LBL-MIM. Installation and maintenance costs are also from the Engineering Analysis. Purchase price and installation costs are added to the present value of operating expenses (including maintenance, if applicable), discounted, and summed over the life of the product. Expenses in future years are discounted to the year of purchase, 1996. For the residential sector, the discount rate is 6% real, with sensitivity analysis performed at 2% and 10% real.

The energy price is the projected 1996 average residential electricity price times an end-use multiplier, 1.04, (see Volume A, Section 5.1.5).

4.1.2 LCC Results

Figure 4.1 shows the LCCs by design option. The values used to produce these figures are presented in Table 4.1.

Figure 4.1 Life-Cycle Cost for a 19" or 20" Color Television Set

Table 4.1 Life-Cycle Costs of 19" or 20" Color Television Sets

Standard Level	Design No.	Design Option	Install. & Maint.	Retail Price	Equipment Price	Energy Factor	Annual Energy Use		Annual Energy Cost	Life-Cycle Costs		
							Gas (MMBtu)	Elec. (kWh)		4%	6%	10%
	0	Baseline	0.00	359.55	359.55	---	0.00	204.86	17.64	519.66	503.13	477.01
1	1	0 + Reduce standby to 2W	0.00	363.31	363.31	---	0.00	183.84	15.83	506.99	492.16	468.71
2	2	1 + Reduce W/B screen power by 6W	0.00	365.94	365.94	---	0.00	170.64	14.69	499.30	485.54	463.78
3	3	2 + Reduce W/B screen power 73W/41	0.00	378.92	378.92	---	0.00	138.52	11.93	487.18	476.00	458.34

Notes: Average lifetime for color TVs is 11.5 years.
 All costs are in 1990 dollars.
 Electricity rate is 8.61 cent/kWh (1996).
 Consumer costs include installation costs but no maintenance costs.

4.2 PAYBACK PERIODS BY STANDARD LEVEL

The payback period (PBP) measures the amount of time needed to recover the additional consumer investment in increased efficiency through lower operating costs. Payback period is found by solving the equation

$$\Delta PC + \sum_{t=1}^{PAY} \Delta OC_t = 0 \quad (4)$$

for *PAY*. 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:

$$PAY = -\frac{\Delta PC}{\Delta OC} \quad (5)$$

Numerically, the PBP is the ratio of the increase in purchase (and installation) price from the base to the standards 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.

4.2.1 PBP Data Inputs

The data inputs are the same as in Section 4.1.1, except that, in addition, a distribution of design options is projected (by LBL-REM) in the base case. Only those designs that are eliminated by the standard level are included in the calculation of impacts. Consumers whose base case choice is eliminated by standards are assumed to purchase the design option corresponding to the minimum compliance with the standard.

4.2.2 PBP Results

The payback periods by standard level shown in Tables 4.2a-d are the weighted-averages. They compare that portion of the projected distribution of designs in the base case that are less efficient than the standard level to the design at the standard level. Designs with energy consumption at or below the standard level are not affected by the standard, so these are excluded from the calculation of impacts.

Tables 4.2a-d show the calculation of LCC differences, payback, and CCE. Table 4.2.a summarizes the equipment cost, operating cost, LCC, and energy use for each design option. Table 4.2.b shows the distribution of units sold in 1996, according to the base case forecast. In the other columns, part of this distribution is expressed as the percent of eliminated units due to standards. That is, if 78% of units sold in the base case correspond to design 0, and standard level 1 (equivalent to design 1) eliminates only design 0, then the fraction of eliminated units due to standard level 1 is 100% for design 0.

Table 4.2.c applies the weights in Table 4.2.b to the values in Table 4.2.a to obtain the weighted average values shown. Table 4.2.d shows the resulting LCC differences, PBPs, and CCE.

4.3 CHANGE IN LIFE-CYCLE COSTS DUE TO STANDARDS

The impact of standards is calculated as the difference in LCC, base case minus standards case. If the LCC difference is greater than zero (positive savings), the standard 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 standard causes a net increase in expenses to the consumer.

4.3.1 Data Inputs for Change in LCC

The data inputs are the same as in Section 4.1.1, except that, in addition, a distribution of design options is projected (by LBL-REM) in the base case. Only those designs that are eliminated by the standard level are included in the calculation of impacts. Consumers whose base case choice is eliminated by standards are assumed to purchase the design option corresponding to the minimum compliance with the standard.

4.3.2 Results for Change in LCC

Table 4.2a shows the LCC differences by standard level. 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 standard level to the design at the standard level. Designs with energy consumption at or below the standard level are not affected by the standard, so these are excluded from the calculation of impacts. These LCCs are calculated at a 6% discount rate; a higher discount rate (e.g., 10%) gives a smaller difference.

Table 4.2.a shows lower LCC (positive LCC difference) for all standard levels for all classes.

4.4 COST OF CONSERVED ENERGY DUE TO STANDARDS

The cost of conserved energy (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:

$$CCE = -\frac{CRF \cdot \Delta PC}{\Delta E} \quad (6)$$

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.

4.4.1 CCE Data Inputs

The data inputs are the same as in Section 4.1.1, except that, in addition, a distribution of design options is projected (by LBL-REM) in the base case. Only those designs that are eliminated by the standard level are included in the calculation of impacts. Consumers whose base case choice is eliminated by standards are assumed to purchase the design option corresponding the minimum compliance with the standard.

4.4.2 CCE Results

Table 4.2d shows the cost of conserved energy at site of the standards levels as compared to the base case. Note that the current (1990) and projected (1996) average residential electricity prices are 8.11 and 8.29 cents per kWh respectively (9). These are equivalent to 23.74 and 23.28 dollars per million Btu, respectively, where one kWh is taken as 3,412 Btu site energy.

All three standard levels have CCEs less than projected costs of energy supply.

Table 4.2.a Cost and Energy-Use Summary 19" or 20" Color Television Sets

Design Number	Equipment Price	Operating Cost	LCC	Annual Energy Use	
	(1990 \$)	(1990 \$)	(1990 \$)	(kWh)	(MMBtu)
0	359.55	17.64	503.13	205	0.70
1	363.31	15.83	492.16	184	0.63
2	365.94	14.69	485.54	171	0.58
3	378.92	11.93	476.00	139	0.47

Table 4.2.b Distribution of Units Sold Below Standards, 19" or 20" Color Television Sets

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
0	72.00%	100.00%	72.00%	72.00%
1	28.00%	<Standard>	28.00%	28.00%
2	0.00%		<Standard>	0.00%
3	0.00%			<Standard>

Table 4.2.c Weighted Averages of Units Sold Below Standards, 19" or 20" Color Television Sets

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
Equip. Price (1990 \$)	359.55	360.60	360.60
Operating Cost (1990 \$)	17.64	17.13	17.13
Life-Cycle Cost (1990 \$)	503.13	500.06	500.06
Energy Use (MMBtu/yr)	0.70	0.68	0.68

Table 4.2.d Life-Cycle Cost Differences (\$1990), Payback Periods (year), and Cost of Conserved Energy (at 6% real), 19" or 20" Color Television Sets

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3
LCC difference	11.0	14.5	24.1
Payback	2.1	2.2	3.5
CCE (cent/kWh)	2.2	2.3	3.7
CCE (\$/MMBtu)	6.4	6.8	10.9

4.5 LCC SENSITIVITY ANALYSIS

The sensitivity of the national LCC results were tested by varying assumptions about energy prices and equipment prices. These tables should be compared to Table 4.1.

Low and high energy prices were defined as the minimum and maximum, respectively, of states' energy prices. Projected (1992) state energy prices (10) relative to the national average were applied to the projected 1996 national average price from the *Annual Energy Outlook 1991* to obtain state prices for 1996. (This represents a wider range of prices than analyzed in previous analyses, which used 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.

Figure 4.2 and Table 4.3 summarize the results of the sensitivity analysis. They include:

- graph of highest and lowest LCC sensitivity, and reference case, and
- table of LCCs for all sensitivity cases. The table also shows the number of sensitivity cases for which each design option is the minimum LCC.

Figure 4.2 Life-Cycle Cost for a 19" or 20" Color Television Set

Table 4.3 Sensitivity Summary of Life-Cycle Costs of Color Television Sets

Standard Level	1	2	3	Std Level @	Design Option
Design Option	0	1	2	3 min LCC	@ min LCC
Reference	503	492	486	476	3
1	438	434	432	432	2
2	521	511	505	499	3
3	456	453	451	455	2
4	571	553	542	522	3
5	485	473	466	453	3
6	553	534	522	499	3
# of cases as min LCC			2	5	

CHAPTER 5. IMPACTS ON THE MANUFACTURERS OF TELEVISIONS

5.1 LONG-RUN IMPACTS

The analysis shows that compared to the 1996 base case, at all trial standards levels, the television industry is likely to experience a return on equity (ROE) decrease. At standards level 1, there is approximately a 65% chance that ROE will decrease, with an expected decrease of 0.02%. At standards level 2 there is approximately a 61% chance of a decrease in ROE with an expected decrease of 0.04%. At standards level 3 there is approximately a 68% chance of a decrease in ROE with an expected decrease of 0.23%. These results are based on 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.

5.1.1 Qualitative Analysis

According to reports from within the industry, television manufacturing is characterized by economies of scale; this means that for the purposes of price determination, there are fixed costs. These 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 standards are imposed, and to the extent that standards induce an increase in variable costs, such costs will be more than completely passed on in the form of a price increase, which in itself is profitable, but which also tends to reduce profit because of the effect of a price increase on sales. If standards induce 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 televisions more attractive and thereby increasing demand. Since demand is specified as a function of purchase price and operating cost (i.e., life-cycle cost) under constant life-cycle cost elasticity, as price changes, so does price elasticity, and consequently, markup. (For instance, as price rises, price elasticity rises, and markup falls.) The model calculates that these effects, when combined, are more likely to reduce economic profits than increase them at all standards levels.

5.1.2 Quantitative Analysis

Table 5.1 summarizes all essential outputs from the LBL-MIM simulations using the primary scenario for televisions. Six scenarios are summarized and discussed in the sensitivity section, Section 5.4.

Table 5.1 Televisions Output Table: Primary Scenario—Long-Run

	1996 BASE	Level 1	Level 2	Level 3
Shipments (in Mil)	1.19	1.18	1.18	1.16
% change		-0.28%	-0.56%	-1.96%
S.E.		0.62%	1.11%	2.85%
Price	\$219.24	\$220.79	\$222.30	\$228.68
% change		0.71%	1.39%	4.30%
S.E.		0.24%	0.49%	1.00%
Revenue (in \$M)	\$260.05	261.15	262.19	265.93
% change		0.42%	0.82%	2.26%
S.E.		0.58%	1.04%	2.85%
Net Income (in \$M)	-3.80	-3.83	-3.87	-4.38
Difference		-0.03	-0.07	-0.59
S.E.		8.48	0.22	3.71
ROE	-1.92%	-1.94%	-1.96%	-2.15
Difference		-0.02%	-0.04%	-0.23%
S.E.		0.06%	0.15%	0.50%

5.2 SHORT-RUN IMPACTS

The business cycle presents the television manufacturing industry with fairly sharp periodic fluctuations in demand, much larger than the fluctuations predicted for any of the standards levels. These normal demand fluctuations present the same types of opportunities for price competition that will accompany fluctuations resulting from a change in standards. 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 televisions; a 10% demand increase has the reverse effect. This effect is taken into account as described in Volume A, Chapter 3, Section 3.3.4.2, and used to produce a short-run version of the output table that is displayed in Table 5.2. Note that at each standards level analyzed for the television-manufacturing industry, the short-run ROE results are generally lower than the long-run results. For reasons that are explained in the above Section, the short-run change has been overestimated. Thus the values for change in Table 5.2 should be viewed as somewhat too large in absolute value.

Table 5.2 Televisions Output Table: Primary Scenario — Short-Run

	1996 BASE	Level 1	Level 2	Level 3
Shipments (in Mil)	1.19	1.18	1.18	1.16
% change		-0.26%	-0.51%	-1.78%
Price	\$219.24	\$220.70	\$222.12	\$228.04
% change		0.67%	1.31%	4.01%
Revenue (in \$M)	260.05	261.11	262.11	265.66
% change		0.41%	0.79%	2.16%
Net Income (in \$M)	-3.80	-3.90	-4.00	-6.76
Difference		-0.10	-0.20	-2.96
ROE	-1.92%	-1.98%	-2.03%	-3.32%
Difference		-0.06%	-0.11%	-1.40%
S.E.		0.11%	0.26%	0.78%

5.3 IMPACT AS A FUNCTION OF FIRM SIZE

Typically in this industry, average cost decreases with increasing firm size, which mean 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 and has culminated in the domination of the market by large foreign firms. The fact that consolidation has been producing larger firms strongly corroborates the finding that large firms have a cost advantage.

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 standards are technologically difficult to meet, they may also hurt selected smaller firms the most, because smaller firms have less sophisticated research and development capabilities. However, since there is only one U.S. manufacturer and that most, if not all of the foreign firms are part of large conglomerates, there are no significant small firms to be affected by standards.

5.4 SENSITIVITY ANALYSIS FOR TELEVISIONS

The three following subsections discuss different aspects of the sensitivity analysis conducted by LBL-MIM. The first subsection, on sensitivity charts, shows the implications of the uncertainty of each control variable for the prediction of ROE. The next subsection shows six alternative scenarios that are of particular importance and deserve a more detailed analysis than those randomly generated by Monte Carlo runs. The last subsection shows the use of Monte

Carlo runs to find combinations of errors that would cause the change in ROE to be considerably more negative than is predicted.

5.4.1 Sensitivity Charts

Table 5.3 lists the sensitivities of ROE to control panel inputs. The variables analyzed are industry price elasticity of demand (IPE), discount rate (RD), the equity cost of capital (ECC), economic profit (EP), the fixed part of costs (FCA), the fixed part of one-time costs (F1X), one-time capital costs (CC.N), one-time variable costs (dVC.N), and the shape parameter of the demand curve (ro.N).

Table 5.3 Televisions Sensitivity Table: Primary Scenario (Sensitivity of ROE to 1 S.E. Change in Control Variable)

Name	Control Variables		Possible Standards Levels		
	Value	Changed	1	2	3
IPE	-0.600	-1.380	-0.03%	-0.06%	-0.26%
RD	250.00%	574.80%	-0.01%	-0.01%	-0.03%
ECC	0.068	0.075	0.00%	0.00%	-0.04%
EP	-0.087	-0.077	0.00%	0.01%	-0.02%
FCA	0.100	0.160	0.01%	0.02%	0.06%
F1X	0.200	0.348	0.00%	0.00%	-0.31%
CC.N	0.000	0.000	0.00%	0.00%	-0.04%
dVC.N	1.548	2.076	-0.01%	-0.02%	-0.04%
ro.N	0.000	0.300	-0.00%	-0.00%	-0.01%

As can be seen from the table, 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 fixed part of one-time costs (F1X), and (3) fixed part of costs (FCA). The reasons that these three variables are important are discussed in the following section.

5.4.2 Alternative Scenarios

The sensitivity analysis shows that price elasticity plays a crucial role in determining the model's output. Note that the price elasticity variable here 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. The estimates of standard errors that are calculated by the Monte Carlo analysis fully acknowledge the uncertainty of this variable. However, in order to show in detail all of the ramifications of changing one or both of them, six alternative scenarios have been run. The six scenarios include low and high price-elasticity scenarios, a constant shipments-scenario (i.e., industry price and operating cost-elasticity set to zero), high and low discount-rate scenarios (i.e.,

high and lower operating-cost scenarios), and a low-discount rate and high price-elasticity scenario. Tables 5.4 through 5.9 show the results of running these six scenarios for the television manufacturing industry.

In these alternative scenarios, note the impact of changes in price elasticity. A high IPE input value lowers ROE, and a lower IPE value increases ROE. This is not surprising since a lower price elasticity implies that demand is less affected by changes in price. As a result, firm profitability should increase relative to the primary scenario since the falloff in demand due to standards-induced price changes is less. The converse is true when price elasticity is higher.

The percentage of fixed costs (FCA) is important because of its role in the model. It determines the LBL-MIM's estimate of the markup over variable cost, which, in turn, determines the firm's ability to pass on various combinations of fixed and variable costs. For a more detailed explanation, see Appendix C of Volume A. The fixed part of one-times costs (FIX) is analogous to FCA except that it applies to each standards level.

5.4.3 Monte Carlo Analysis

The Monte Carlo approach is described in Volume A, Chapter 3, Section 3.3.4.3 and the standard errors it generates are reported in Tables 5.4 through 5.9. Table 5.10 shows the control panels from two Monte Carlo runs, which were selected because they show a decrease in long-run ROE. Both Monte Carlo runs were done on standards level 2. In the first run, large increases in price elasticity coupled with increases in the percentage of both fixed costs and one-time costs (which are not passed through via prices) and the discount rate are the primary factors in reducing ROE. In the second, increases in price elasticity and one-time costs with a smaller increase in the discount rate reduce ROE despite a small decrease in fixed costs.

Table 5.4 Televisions Output Table: High Industry-Price-Elasticity Scenario

	1996 BASE	Level 1	Level 2	Level 3
Shipments (in Mil)	1.19	1.18	1.17	1.14
% change		-0.56%	-1.12%	-3.88%
SE		0.27	0.55%	1.03%
Price	\$219.24	\$220.79	\$222.30	\$228.68
% change		0.71%	1.39%	4.30%
SE		0.23%	0.47%	0.93%
Revenue (in \$M)	260.05	260.42	260.71	260.71
% change		0.14%	0.25%	0.26%
SE		0.05%	0.10%	0.19%
Net Income (in \$M)	-3.80	-3.87	-3.94	-4.71
Difference		-0.07	-0.14	-0.92
S.E.		0.05	0.10	0.71
ROE	-1.92%	-1.97%	-2.01%	-2.35%
Difference		-0.05%	-0.09%	-0.43%
S.E.		0.03%	0.06%	0.34%

Table 5.5 Televisions Output Table: Low Industry-Price-Elasticity Scenario

	1996 BASE	Level 1	Level 2	Level 3
Shipments (in Mil)	1.19	1.19	1.19	1.19
% change		-0.00%	-0.00%	-0.00%
S.E.		0.00%	0.00%	0.00%
Price	\$219.24	\$220.79	\$222.30	\$228.68
% change		0.71%	1.39%	4.30%
S.E.		0.22%	0.43%	0.88%
Revenue (in \$M)	260.05	261.89	263.67	271.24
% change		0.71%	1.39%	4.30%
S.E.		0.22%	0.43%	0.88%
Net Income (in \$M)	-3.80	-3.80	-3.79	-4.05
Difference		0.00	0.01	-0.25
S.E.		0.08	0.11	0.69
ROE	-1.92%	-1.92%	-1.92%	-1.95%
Difference		0.00%	0.00%	-0.03%
S.E.		0.04%	0.06%	0.32%

Table 5.6 Televisions Output Table: Constant-Shipments Scenario – Long-Run

	1996 BASE	Level 1	Level 2	Level 3
Shipments (in Mil)	1.19	1.19	1.19	1.19
% change		-0.00%	-0.00%	-0.00%
S.E.		0.00%	0.00%	0.00%
Price	\$219.24	\$220.79	\$222.30	\$228.68
% change		0.71%	1.39%	4.30%
S.E.		0.23%	0.46%	0.93%
Revenue (in \$M)	260.05	261.89	263.67	271.24
% change		0.71%	1.39%	4.30%
S.E.		0.23%	0.46%	0.93%
Net Income (in \$M)	-3.80	-3.80	-3.79	-4.05
Difference		0.00	0.01	-0.25
S.E.		0.07	0.15	0.80
ROE	-1.92%	-1.92%	-1.92%	-1.95%
Difference		0.00%	0.00%	-0.03%
S.E.		0.04%	0.07%	0.38%

Table 5.7 Televisions Output Table: Low-Discount-Rate Scenario – Long-Run

	1996 BASE	Level 1	Level 2	Level 3
Shipments (in Mil)	1.19	1.22	1.26	1.34
% change		3.25%	6.26%	13.24%
S.E.		0.21%	0.39%	1.04%
Price	\$219.24	\$220.76	\$222.24	\$228.54
% change		0.69%	1.37%	4.24%
S.E.		0.31%	0.55%	1.11%
Revenue (in \$M)	260.05	270.35	280.10	306.98
% change		3.96%	7.71%	18.05%
S.E.		0.12%	0.23%	0.63%
Net Income (in \$M)	-3.80	-3.39	-3.01	-1.90
Difference		0.41	0.79	1.89
S.E.		0.21	0.32	0.98
ROE	-1.92%	-1.66%	-1.44%	-0.82%
Difference		0.26%	0.48%	1.10%
S.E.		0.10%	0.15%	0.43%

Table 5.8 Televisions Output Table: High Discount-Rate Scenario – Long-Run

	1996 BASE	Level 1	Level 2	Level 3
Shipments (in Mil)	1.19	1.18	1.18	1.16
% change		-0.32%	-0.64%	-2.12%
S.E.		0.14%	0.25%	0.54%
Price	\$219.24	\$220.79	\$222.30	\$228.68
% change		0.71%	1.39%	4.31%
S.E.		0.23%	0.43%	0.95%
Revenue (in \$M)	260.05	261.05	261.99	265.51
% change		0.38%	0.75%	2.10%
S.E.		0.09%	0.17%	0.37%
Net Income (in \$M)	-3.80	-3.84	-3.88	-4.41
Difference		-0.04	-0.08	-0.61
S.E.		0.05	0.08	0.70
ROE	-1.92%	-1.95%	-1.97%	-2.17%
Difference		-0.03%	-0.05%	-0.25%
S.E.		0.03%	0.04%	0.34%

Table 5.9 Televisions Output Table: Low-Discount-Rate and High-Price-Elasticity Scenario - Long-Run

	1996 BASE	Level 1	Level 2	Level 3
Shipments (in Mil)	1.19	1.26	1.34	1.52
% change		6.60%	12.91%	28.24%
S.E.		0.45%	1.24%	4.18%
Price	\$219.24	\$220.76	\$222.24	\$228.54
% change		0.69%	1.37%	4.24%
S.E.		0.32%	0.73%	1.54%
Revenue (in \$M)	260.05	279.13	297.63	347.63
% change		7.34%	14.45%	33.68%
S.E.		0.14%	0.53%	2.53%
Net Income (in \$M)	-3.80	-2.94	-2.12	0.65
Difference		0.86	1.68	4.44
S.E.		0.42	0.99	1.89
ROE	-1.92%	-1.40%	-0.96%	0.25%
Difference		0.52%	0.96%	2.17%
S.E.		0.20%	0.44%	0.71%

Table 5.10 Televisions. Monte Carlo Runs: Searching for Low ROE

TELEVISIONS CONTROL FACTORS	Scenario: Primary		Standard Level = 2		
	Input Value	Cntrl	Vari- ation	Program Value	Name
Price Elasticity	-0.600	1.54	100%	-2.158	IPE
Consumer Discount Rate	250.00%	0.21	100%	298.56%	RD
Equity Cost of Capital	0.068	-2.21	10%	0.055	ECC
Economic Profit	-0.087	-1.02	1%	-0.097	EP
L-R Fixed Part of Costs & Assets	0.100	1.09	50%	0.168	FCA
L-R Fixed Part of 1-X Cap. Cost	0.200	0.29	60%	0.234	FIX
One-Time Capital Costs	0.000	1.58	20%	0.000	CC.N
Unit Variable Cost Increase	\$3.05	1.00	30%	4.086	dVC.N
Elasticity Curve Parameter	0.000	0.62	30%	0.187	ro.N
Short-Run Price Response to Demand	0.157	0.94	76%	0.545	SRPR
SUMMARY	NAECA	NEW		PERVIOUS	NEW
	BASE	L-RUN	CHANGE	CHANGE	S-RUN
Shipments	1.19	1.15	-3.23%	-0.56%	1.17
Price	\$219.24	\$223.41	1.90%	1.39%	\$221.63
Revenue (in \$M)	260.05	256.44	-1.39%	0.82%	259.04
Net Income	-8.47	-9.07	-0.60	-0.07	-10.08
ROE	-4.28%	-4.72%	-0.44%	-0.04%	-5.25%
08-Sep-92	15:17	Trys =		13.00	

TELEVISIONS CONTROL FACTORS	Scenario: Primary		Standard Level = 2		
	Input Value	Cntrl	Vari- ation	Program Value	Name
Price Elasticity	-0.600	2.33	100%	-4.186	IPE
Consumer Discount Rate	250.00%	0.05	100%	260.29%	RD
Equity Cost of Capital	0.068	-1.30	10%	0.060	ECC
Economic Profit	-0.087	0.21	1%	-0.085	EP
L-R Fixed Part of Costs & Assets	0.100	-0.28	50%	0.088	FCA
L-R Fixed Part of 1-X Cap. Cost	0.200	1.16	60%	0.381	FIX
One-Time Capital Costs	0.000	-1.54	20%	0.000	CC.N
Unit Variable Cost Increase	\$3.05	0.04	30%	3.081	dVC.N
Elasticity Curve Parameter	0.000	0.47	30%	0.142	ro.N
Short-Run Price Response to Demand	0.157	-0.77	76%	0.057	SRPR
SUMMARY	NAECA	NEW		PERVIOUS	NEW
	BASE	L-RUN	CHANGE	CHANGE	S-RUN
Shipments	1.19	1.14	-3.99%	-0.56%	1.15
Price	\$219.24	\$222.32	1.40%	1.39%	\$221.91
Revenue (in \$M)	260.05	253.18	-2.64%	0.82%	254.79
Net Income	-5.02	-5.42	-0.40	-0.07	-5.65
ROE	-2.54%	-2.85%	-0.31%	-0.04%	-2.97%
08-Sep-92	15:36	Trys =		44.00	

CHAPTER 6. IMPACTS OF STANDARDS ON ELECTRIC UTILITIES: TELEVISIONS

6.1 INTRODUCTION

Appliance efficiency standards 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 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 standard levels. The fourth section presents the results of the revenue loss calculation. More details on methodology may be found in Appendix E of Volume A.

6.2 AVOIDED ENERGY AND AVOIDED RELIABILITY COSTS

Figure 6.1 shows avoided energy and reliability costs for electricity savings from televisions.³ These figures show the sum of avoided costs for the base-, high-, and low-energy price cases.⁴ The value per million Btu (MMBtu) of avoided reliability costs is the same in all three energy price cases. The avoided fuel and capital component depends on fuel prices and implicitly contains the costs avoided when baseload power plants are deferred or canceled (it also contains avoided transmission and distribution 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. They are used in the LBL-REM to value electricity savings from the societal perspective.

³The total avoided costs for televisions vary slightly by policy case because the conservation load factors vary depending on the percentage of total energy savings attributable to standby losses. We only show one graph here because the variation in avoided costs over the policy cases is around 1%. See Appendix E in Volume A for more details.

⁴Fuel price forecasts for the period 1990 to 2000 are taken from the DOE/EIA *Annual Energy Outlook 1991* (DOE/EIA-0383(91)). The forecasts for years after 2000 were linearly extrapolated using the methodology described in Volume A. The high- (low-) energy price case is derived by increasing (decreasing) the reference case AEO fuel price forecasts for gas and coal by 5%.

6.3 PEAK LOAD AND CAPACITY REDUCTIONS

Table 6.1 shows peak load reductions for televisions for the relevant standards levels. Table 6.2 shows capacity savings for televisions for the relevant standards levels. The base case peak load in the second column of Table 6.1 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 transmission and distribution loss factor of 1.075, and estimates of energy consumption calculated using the LBL-REM. Capacity savings are peak-load savings in regions that need additional capacity, multiplied by 1.2 to account for reserve margin needed for adequate reliability. The amount of capacity saved can be somewhat less than the peak-demand savings in years before 1999 because capacity savings are only counted in regions that need capacity. After 1998, capacity savings consistently exceed peak-load savings by the reserve margin of 20% (numbers may not exactly correspond to this rule because of rounding errors).

Peak-demand reductions from the standards for televisions range from 0.2 to 0.7 GW in 2000, and from 0 to 1.1 GW in 2030. Capacity savings for televisions range from 0.2 to 0.9 GW in 2000, and from 0 to 1.3 GW in 2030.

Figure 6.1 Utility Avoided Costs for Televisions

Table 6.1 Peak Demand Reductions (GW) - Televisions

Year	Peak Load	Peak Demand Savings		
		Level 1	Level 2	Level 3
1996	3.4	0.1	0.1	0.3
1997	3.4	0.1	0.2	0.4
1998	3.5	0.1	0.2	0.5
1999	3.6	0.1	0.3	0.6
2000	3.7	0.2	0.3	0.7
2001	3.7	0.2	0.4	0.8
2002	3.8	0.2	0.4	1.0
2003	3.9	0.2	0.5	1.0
2004	4.0	0.3	0.5	1.1
2005	4.0	0.3	0.5	1.2
2006	4.1	0.3	0.5	1.2
2007	4.1	0.3	0.6	1.2
2008	4.2	0.3	0.6	1.2
2009	4.2	0.3	0.6	1.3
2010	4.2	0.3	0.6	1.3
2011	4.3	0.3	0.6	1.3
2012	4.3	0.3	0.6	1.3
2013	4.4	0.3	0.6	1.3
2014	4.4	0.3	0.6	1.3
2015	4.4	0.2	0.5	1.3
2016	4.4	0.2	0.5	1.2
2017	4.4	0.2	0.5	1.2
2018	4.4	0.2	0.5	1.2
2019	4.4	0.1	0.4	1.2
2020	4.4	0.1	0.4	1.1
2021	4.4	0.1	0.4	1.1
2022	4.4	0.0	0.3	1.1
2023	4.4	0.0	0.3	1.1
2024	4.4	0.0	0.3	1.1
2025	4.4	0.0	0.3	1.1
2026	4.5	0.0	0.3	1.1
2027	4.5	0.0	0.3	1.1
2028	4.5	0.0	0.3	1.1
2029	4.6	0.0	0.3	1.1
2030	4.6	0.0	0.3	1.1

Table 6.2 Capacity Savings (GW) - Televisions

Year	Capacity Savings		
	Level 1	Level 2	Level 3
1996	0.0	0.1	0.2
1997	0.1	0.1	0.3
1998	0.1	0.2	0.4
1999	0.2	0.3	0.7
2000	0.2	0.4	0.9
2001	0.2	0.5	1.0
2002	0.3	0.5	1.1
2003	0.3	0.6	1.3
2004	0.3	0.6	1.3
2005	0.3	0.6	1.4
2006	0.3	0.7	1.5
2007	0.3	0.7	1.5
2008	0.3	0.7	1.5
2009	0.3	0.7	1.5
2010	0.3	0.7	1.5
2011	0.3	0.7	1.5
2012	0.3	0.7	1.5
2013	0.4	0.7	1.6
2014	0.3	0.7	1.5
2015	0.3	0.6	1.5
2016	0.3	0.6	1.5
2017	0.2	0.6	1.5
2018	0.2	0.5	1.4
2019	0.2	0.5	1.4
2020	0.1	0.5	1.4
2021	0.1	0.4	1.4
2022	0.1	0.4	1.3
2023	0.0	0.4	1.3
2024	0.0	0.4	1.3
2025	0.0	0.4	1.3
2026	0.0	0.4	1.3
2027	0.0	0.4	1.3
2028	0.0	0.4	1.3
2029	0.0	0.4	1.3
2030	0.0	0.4	1.3

6.4 REVENUE LOSSES

Appliance standards allow utilities to avoid the variable costs of generating electricity, but standards also reduce electricity sales. In a 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 standards 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, use the most current information on the impacts of appliance efficiency standards.

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 standards 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 do 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 that assumes that regulators adjust the rates to reflect the reduced sales in five years and one that assumes that they never adjust the rates. These cases also assume that there is no unanticipated 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 standards, 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 standards 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-standard sales forecast, this case is included as an absolute upper bound. Figure 6.2 shows annual revenue losses and avoided costs over time for level 3 standards, and Table 6.3 shows net revenue losses for all standards levels. Cumulative net revenue losses for televisions range from \$1.4 to 6.9 billion.

Figure 6.2

Revenue Reductions and Avoided Costs for Televisions

Table 6.3 Net Revenue Losses - Televisions (Million 1990 Dollars)

Year	Net Revenue Losses		
	Level 1	Level 2	Level 3
1996	28	50	96
1997	37	67	132
1998	46	84	169
1999	51	93	189
2000	59	107	219
2001	66	120	246
2002	71	130	269
2003	75	138	285
2004	77	142	296
2005	77	142	299
2006	77	142	300
2007	77	141	298
2008	75	139	293
2009	74	137	289
2010	73	134	284
2011	71	131	276
2012	69	127	267
2013	67	123	259
2014	59	113	245
2015	51	103	230
2016	43	94	215
2017	36	84	201
2018	29	75	188
2019	22	67	174
2020	17	59	161
2021	11	52	148
2022	6	45	136
2023	3	39	125
2024	1	35	115
2025	0	32	107
2026	0	29	99
2027	0	27	90
2028	0	25	82
2029	0	22	74
2030	0	20	65
Total	1447	3069	6921

The figures in Table 6.3 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. Total residential rates would increase 0.3% and 0.3% (0.02¢/kWh and 0.03¢/kWh) in 2000 and 2005, respectively, if televisions are subject to level 3 standards and regulators only change commercial rates to compensate for any loss in revenue.

Table 6.4 shows the present value of net revenue losses at a 5% real utility discount rate for all standard 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 6.4 Present Value of Revenue Losses - Televisions (Million 1990 Dollars)

Regulatory Lag	Level 1	Level 2	Level 3
None	0	0	0
1996-2001	147	267	537
1996-2030	645	1267	2738

For televisions, the present value of net lost revenues may range from \$0.1 to 0.5 billion for a five-year lag, and would be as large as \$2.7 billion if the regulators did not make adjustments. The present values over the period 1996 to 2030 also represent the rate increases needed over this period to compensate for lost revenues, assuming that regulators adjust immediately.

6.5 SENSITIVITY ANALYSIS

Tables 6.5 and 6.6 show the peak-demand reductions and capacity savings for the sensitivity cases. Table 6.7 shows the present value of net lost revenues for the same sensitivity cases. The assumptions for the sensitivity cases are the same as those for previous tables.

Table 6.5 Peak-Demand Reductions (GW) - Televisions (Sensitivity Cases)

Year	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
1996	0.2	0.3	0.3	0.3	0.2	0.2
2000	0.4	0.7	0.7	0.7	0.5	0.6
2010	0.7	1.3	1.3	1.2	0.2	0.7
2020	0.7	1.4	1.4	1.0	0.0	0.7
2030	0.8	1.5	1.1	1.0	0.0	0.8

Table 6.6 Capacity Savings (GW) - Televisions (Sensitivity Cases)

Year	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
1996	0.1	0.2	0.2	0.2	0.2	0.1
2000	0.5	0.9	0.9	0.9	0.6	0.7
2010	0.8	1.5	1.5	1.4	0.3	0.8
2020	0.9	1.7	1.6	1.2	0.0	0.9
2030	0.9	1.8	1.3	1.2	0.0	0.9

Table 6.7 Present Value of Net Lost Revenues (Million 1990 \$) - Televisions (Sensitivity Cases)

Regulatory Lag	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
None	0	0	0	0	0	0
1996-2001	309	629	612	560	398	430
1996-2030	1582	3817	3662	2754	999	1846

CHAPTER 7. ENVIRONMENTAL EFFECTS

7.1 INTRODUCTION

The environmental effects from a range of new candidate energy-conservation standards for televisions are presented here. The results are presented for each potential standard level. Each measure of possible environmental change is an alternative action, and it is compared to what is expected to happen if no new standards for televisions were finalized, i.e., the "no action" alternative.

The environmental concern addressed is emissions from fossil-fueled electricity generation. All of the design options for televisions result in decreased electricity use and, therefore, a reduction in power plant emissions. The proposed efficiency standards will 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, or 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 is considered an environmental hazard because it contributes to the "greenhouse effect" by trapping heat energy from the earth that is emitted as infrared radiation. The "greenhouse effect" is expected to gradually raise the mean global temperature.

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

7.2 RESULTS

The following tabular results indicate what changes can be brought about in the amounts of emitted CO_2 , SO_2 , and NO_x by imposing efficiency standards for televisions. A table is presented for each of the trial standard levels. Each table details the changes that occur to each of the three emissions (i.e., CO_2 , SO_2 , and NO_x) through the imposition of a specific trial standard level. Each table includes the following information for a specific year between 1996 and 2030: the amount of emission abated from power plant generation, the amount abated from in-home 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 1996 and 2030).

Decreases in the amounts of CO_2 , SO_2 , and NO_x emitted at trial standards levels 1 through 3 are summarized in Tables 7.1 through 7.3.

7.2.1 Sulfur and Nitrogen Oxide Emissions

SO₂ emissions would be decreased by a cumulative total of up to 0.60 million tons between 1996 and 2030 in the level 3 scenario. In the year 1996, decreases in SO₂ will represent about 0.08% of the SO₂ emissions estimated to come from power plants in that year. In the year 2030, decreases in SO₂ emissions will represent about 0.16% of the SO₂ emissions estimated to come from power plants in that year. Because of provisions in the Clean Air Act Amendments (Pub. L. 101-549, November 15, 1990), the possible reductions of SO₂ that are caused by standards can be earned as credits by the utility realizing the reductions. To the extent SO₂ credits are used for future emissions, the net effect on SO₂ emissions from standards would be only a postponement of those SO₂ emissions.

Level 3 design changes to televisions would result in an estimated decrease in NO_x emissions of 0.53 million tons between 1996 and 2030. NO_x decreases would represent 0.08% and 0.16% of the NO_x emissions estimated to come from power plants in the years 1996 and 2030, respectively.

7.2.2 Carbon Dioxide Emissions

The cumulative reduction in CO₂ emissions from level 3 design changes is 263 million tons of CO₂. For the year 1996, the estimated CO₂ reduction is 1902 thousand tons of CO₂ or about 0.08% of estimated U.S. total CO₂ emissions in 1996. For the year 2030, the estimated CO₂ reduction is 7774 thousand tons of CO₂, or about 0.16% of estimated U.S. total CO₂ emissions in 2030.

Table 7.1
Reduction of Pollutants for Televisions - Level One

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	542	0	542	0.02%
2000	1,342	0	1,342	0.05%
2005	2,112	0	2,112	0.07%
2010	2,269	0	2,269	0.07%
2015	1,913	0	1,913	0.05%
2020	801	0	801	0.02%
2025	0	0	0	0.00%
2030	0	0	0	0.00%

Cumulative CO2 reduction, 1996-2030 = 43 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	3,044	0	3,044	0.02%
2000	4,818	0	4,818	0.05%
2005	6,419	0	6,419	0.07%
2010	5,922	0	5,922	0.07%
2015	4,020	0	4,020	0.05%
2020	1,354	0	1,354	0.02%
2025	0	0	0	0.00%
2030	0	0	0	0.00%

Cumulative SO2 reduction, 1996-2030 = 120,177 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change (tons)	%U.S. NOx Power Plant Emissions
1996	1,911	0	1,911	0.02%
2000	3,586	0	3,586	0.05%
2005	5,165	0	5,165	0.07%
2010	5,146	0	5,146	0.07%
2015	3,727	0	3,727	0.05%
2020	1,354	0	1,354	0.02%
2025	0	0	0	0.00%
2030	0	0	0	0.00%

Cumulative NOx reduction, 1996-2030 = 99,428 tons

Table 7.2
Reduction of Pollutants for Televisions - Level Two

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	981	0	981	0.04%
2000	2,482	0	2,482	0.10%
2005	3,937	0	3,937	0.14%
2010	4,241	0	4,241	0.13%
2015	3,977	0	3,977	0.11%
2020	2,943	0	2,943	0.07%
2025	2,195	0	2,195	0.05%
2030	2,268	0	2,268	0.05%

Cumulative CO2 reduction, 1996-2030 = 108 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	5,509	0	5,509	0.04%
2000	8,912	0	8,912	0.10%
2005	11,965	0	11,965	0.14%
2010	11,067	0	11,067	0.13%
2015	8,361	0	8,361	0.11%
2020	4,974	0	4,974	0.07%
2025	2,879	0	2,879	0.05%
2030	2,266	0	2,266	0.05%

Cumulative SO2 reduction, 1996-2030 = 261,149 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change (tons)	%U.S. NOx Power Plant Emissions
1996	3,458	0	3,458	0.04%
2000	6,635	0	6,635	0.10%
2005	9,627	0	9,627	0.14%
2010	9,618	0	9,618	0.13%
2015	7,751	0	7,751	0.11%
2020	4,974	0	4,974	0.07%
2025	3,155	0	3,155	0.05%
2030	2,786	0	2,786	0.05%

Cumulative NOx reduction, 1996-2030 = 225,217 tons

Table 7.3
Reduction of Pollutants for Televisions - Level Three

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	1,902	0	1,902	0.08%
2000	5,115	0	5,115	0.20%
2005	8,364	0	8,364	0.29%
2010	9,052	0	9,052	0.28%
2015	8,987	0	8,987	0.25%
2020	8,146	0	8,146	0.21%
2025	7,555	0	7,555	0.17%
2030	7,774	0	7,774	0.16%

Cumulative CO2 reduction, 1996-2030 = 263 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	10,680	0	10,680	0.08%
2000	18,367	0	18,367	0.20%
2005	25,420	0	25,420	0.29%
2010	23,620	0	23,620	0.28%
2015	18,891	0	18,891	0.25%
2020	13,767	0	13,767	0.21%
2025	9,908	0	9,908	0.17%
2030	7,767	0	7,767	0.16%

Cumulative SO2 reduction, 1996-2030 = 599,166 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change (tons)	%U.S. NOx Power Plant Emissions
1996	6,704	0	6,704	0.08%
2000	13,673	0	13,673	0.20%
2005	20,453	0	20,453	0.29%
2010	20,526	0	20,526	0.28%
2015	17,515	0	17,515	0.25%
2020	13,767	0	13,767	0.21%
2025	10,855	0	10,855	0.17%
2030	9,547	0	9,547	0.16%

Cumulative NOx reduction, 1996-2030 = 527,742 tons

APPENDIX A. MANUFACTURER COST DATA FOR TELEVISIONS

The following table shows the manufacturing costs (1990\$) for several design options for color televisions with remote control and electronic tuning. The total incremental manufacturing cost is disaggregated into four subcategories: labor, materials, purchased parts, and tooling. The 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 for each design option is plus or minus 25%.

Standard Level	Design	Labor	Materials	Parts	Tooling	Total Cost
Baseline	Baseline					174.00
1	0 + Reduced Stdby	0.00	0.00	2.15	0.00	176.15
2	1 + Eff. Power Supply	0.00	0.00	1.50	0.00	177.65
3	2 + Eff. Design	0.00	0.00	1.60	5.00	184.25

APPENDIX B. LBL-REM INPUT DATA: TELEVISIONS

The complete input listing is available on electronic medium in ASCII format. The input database includes demographic, economic, and engineering data.

The following is the regular LBL-REM input for televisions.

For standards cases, simply replace the input values for two variables in each class of each product regulated. The two variables are labelled: "first year for standard" and "UEC of standard." For example, for television standards taking effect in 1996, change "first year for standard = 2031" to "first year for standard = 1996" and enter the appropriate maximum UEC value in the line "UEC of standard."

Television
total saturation = 2.50
elec price multiplier = 1.04
gas price multiplier = 1.00
ncalc = 2
ndr1 (1, read drate & curve) = 1
nv1 (# of eun inputs) = 0
nv5 (# of cap inputs) = 0
nv2 (# of peq inputs) = 0
nv4 (# of usage inputs) = 2
ndis (year to forecast eff) = 11

----- UEC of stock unit in base year by fuel type i (MMBTU/yr) -----

1	2	3	4	5	
0.4069	2.4796	0.00	0.00	0.00	** SF **
0.4069	2.4796	0.00	0.00	0.00	** MF **
0.4069	2.4796	0.00	0.00	0.00	** MB **

----- Purchase price of a reference unit (\$1990) -----

1	2	3	4	5	
66.00	359.55	0.00	0.00	0.00	** SF **
66.00	359.55	0.00	0.00	0.00	** MF **
66.00	359.55	0.00	0.00	0.00	** MB **

----- Relative UEC and Capacity of a reference unit to a stock unit -----

1	2	3	4	5	
0.9298	0.9228	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	
0.750	1.250	0.000	0.000	0.000	0.500	** SF **
0.600	0.800	0.000	0.000	0.000	1.100	** MF **

0.421 0.939 0.000 0.000 0.000 1.140 ** MB **

----- Marginal Saturations for Replacement Units - cn(m=1) -----

1	2	3	4	5	6	
0.697	1.803	0.000	0.000	0.000	0.000	** SF **
0.751	1.749	0.000	0.000	0.000	0.000	** MF **
0.735	1.765	0.000	0.000	0.000	0.000	** MB **

----- Marginal Saturations for New Houses - cn(m=2) -----

1	2	3	4	5	6	
0.743	1.319	0.000	0.000	0.000	0.438	** SF **
0.413	0.945	0.000	0.000	0.000	1.142	** MF **
0.513	1.102	0.000	0.000	0.000	0.885	** MB **

----- Historical Shipments (from 1980 to 30 years back) -----

1 B/W TV

6149.	6281.	6064.	5699.	5333.	4968.	4884.	4799.	4715.	4630.
4546.	4462.	4377.	4293.	4208.	4124.	4040.	3955.	3871.	3786.
3702.	3618.	3618.	3618.	3618.	3618.	3618.	3618.	3618.	3618.

2 Color TV

9978.	9793.	10236.	8986.	7735.	6485.	6152.	5820.	5487.	5155.
4822.	4489.	4156.	3823.	3490.	3157.	2824.	2491.	2158.	1825.
1492.	1159.	826.	593.	260.	0.	0.	0.	0.	0.

----- Retirement Function (from age 1 to 30 years) -----

for i 1

0.0000	0.0000	0.0000	0.1000	0.2000	0.2000	0.2000	0.2000	0.1000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

for i 2

0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2000	0.3000
0.3000	0.2000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

----- Average Life Times (by fuel type i) -----

1	2	3	4	5
6.5	11.5	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	-0.15	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	-0.585	/* j=6 */

----- Real Interest Rate for calc of Price Elast. (for 5 fuel types) -----

1	2	3	4	5	
0.15	0.00	0.00	0.00	0.00	/* j=1 */
0.00	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	0.00	0.00	0.00	0.00	/* j=6 */

----- Discount Rates for Replacement Units (m=1) -----

1	2	3	4	5	
0.348	0.000	0.000	0.000	0.000	** SF **
0.346	0.000	0.000	0.000	0.000	** MF **
0.344	0.000	0.000	0.000	0.000	** MB **

----- Discount Rates for New Units (m=2) -----

1	2	3	4	5	
0.348	0.000	0.000	0.000	0.000	** SF **
0.346	0.000	0.000	0.000	0.000	** MF **
0.344	0.000	0.000	0.000	0.000	** MB **

----- Cost-Efficiency Curve Parameters -----

1	2	3	4	5	
0.8621	0.00	0.00	0.00	0.00	** einf **
10.4137	0.00	0.00	0.00	0.00	** ealfa **

----- Historical Usage Factors for Existing Units -----

i	1	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2	0	.636364	.636364	.636364	.636364	.636364	.636364	.636364	.636364	.636364	.636364	.636364

of products in Television = 2

```
=====
product type id#      = 24
product name         = BWTv (B/W Television)
end-use id#          = 17
fuel type id#         = 1
number of classes     = 1
```

----- the 1st class -----

```
class id#             = 92
class name            = Mono (Monochrom TV)
discount rate         = 0.51
first year to forecast UEC = 1990
first year for standard = 2031
```


UEC of standard = 966.5
conversion (Kwh-MMBTU&usage) = .003412

----- Historical energy factors (100/32.90) / .992 per year
1981 1982 1983 1984 1985 1986 1987 1988 1989 1990
3.0640 3.0887 3.1136 3.1388 3.1641 3.1896 3.2153 3.2412 3.2674 3.2690

----- Adjusted volumes (1981-2030) (100/365)
.273973 .273973 .273973 .273973 .273973 .273973 .273973 .273973 .273973 .273973
.273973 .273973 .273973 .273973 .273973 .273973 .273973 .273973 .273973 .273973
.273973 .273973 .273973 .273973 .273973 .273973 .273973 .273973 .273973 .273973
.273973 .273973 .273973 .273973 .273973

----- Fraction of market share (1981-2030)
1 = 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
66.00 32.90
66.54 31.24
67.82 30.57

----- Shipment Distribution
EF Units
3.0640 1.

=====

product type id# = 25
product name = C TV (Television)
end-use id# = 17
fuel type id# = 2
number of classes = 1

----- the 1st class -----
class id# = 93
class name = Colr (Color TV)
discount rate = 0.51
first year to forecast UEC = 1990
first year for standard = 2031
UEC of standard = 966.5
conversion (Kwh-MMBTU&usage) = .003412

----- Historical energy factors (1990 uec = .72*204.86+.28*183.84, 100/1990uec=.50258)
1981 1982 1983 1984 1985 1986 1987 1988 1989 1990
.46753 .47130 .47510 .47893 .48279 .48669 .49061 .49457 .49856 .50258

----- Adjusted volumes (1981-2030) (100/365)

.273973 .273973 .273973 .273973 .273973 .273973 .273973 .273973 .273973 .273973
 .273973 .273973 .273973 .273973 .273973 .273973 .273973 .273973 .273973 .273973
 .273973 .273973 .273973 .273973 .273973 .273973 .273973 .273973 .273973 .273973
 .273973 .273973 .273973 .273973 .273973

----- 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
359.55	204.86
360.60	198.97
363.31	183.84
365.94	170.64
378.92	138.52

----- Shipment Distribution

EF	Units
.50258	1.

APPENDIX C. LBL MANUFACTURER IMPACT MODEL: TELEVISIONS

C.1 INTRODUCTION

The Lawrence Berkeley Laboratory Manufacturer Impact Model (LBL-MIM) collects all the calculations necessary to determine the impact of a change in appliance efficiency standards on an industry's profitability and scale of operation into one spreadsheet. Volume A, Appendix C provides an overview and description of the LBL-MIM along with a description of the economic theory and a discussion of each of the model's modules. In this appendix, the LBL-MIM input data and model runs for the analysis of television sets are described together.

C.1.1 Engineering Cost Data

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

1. The incremental unit variable cost incurred by the manufacturer for each of the design options that increases the efficiency of the appliance such as 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 unit energy consumption (UEC) associated with each design option for each product class.
3. 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 as one figure for each design option requiring capital expenditures; the single figure covers all of the product classes.

The engineering input data are also listed for each standards level being analyzed (a 1990 calibration case, a 1996 base case using the 1990 standards, and standards levels 1, 2, 3, etc., 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 standards levels instead. The engineering data used as inputs to the LBL-MIM 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. For a thorough description of the collection and meaning of the engineering data, see Chapter 1 of this volume, Engineering Analysis.

C.1.2. Industry Market Data

Industry Shipments

These data include annual industry shipments for the 1990 calibration case, the 1996 base case (using the 1990 standards), and the 1996 shipments for each of the standards levels. The 1990 shipments figure is based on statistics from *Appliance*, *Appliance Manufacturer*, and the LBL-REM.

Elasticities

Price and operating cost elasticities determine the effect on shipments of changes in appliance price and operating cost. For televisions, the price elasticity is estimated to be -0.6. The consumer discount rate supplied by the LBL-REM was 250% and thus an operating cost elasticity of -0.02. The source of these elasticities is LBL. Because these elasticities are very important, a sensitivity analysis using different elasticities is done.

Product Class Market Share

Each of the product classes has a share of the total market for televisions, and the market share, or unit sales, for each product class is an input to the model. For televisions, only color televisions were considered because black and white televisions make up a very small (and decreasing) percentage of the market.

Markups

Manufacturers charge different markups over variable cost for different product classes, resulting in different profit margins for different product classes. For televisions, the estimated markup is 1.4. The source is research by the Manufacturer Analysis team along with the Engineering Analysis.

Initial Prices

The 1990 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 the Manufacturer Analysis team.

Energy Price

This figure is the ratio of the price of a 1990 kWh to a 1996 kWh. The source is the LBL-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 televisions 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 ¹	6.8%	MIM calc. from public financial data ²
Interest rate on debt ¹	2.5%	MIM calc. from public financial data
Interest lost in cash ¹	1.0%	MIM calc. from public financial data
Rate of depreciation	17.7%	Public financial data
Tax rate	34.0%	Tax law

¹Cost of capital and interest rate are *real* rather than nominal.

²Public financial data include data from Value Line, Standard and Poor's, Moody's, individual company annual reports, and economic reports.

Table C.2 Other Financial Data

Variable	Value	Source
Cash	4.6%	Public financial data
Inventory and receivables	29.9%	Public financial data
Net depreciable assets	25.1%	Public financial data
General and administrative expenses	13.3%	Public financial data
Engineering expense	1.2%	Public financial data and industry sources ¹

¹Industry sources include consultants under contract to LBL and discussions with industry representatives.

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

Variable	Value	Source
Fixed part of costs and depr. assets	10.2%	Industry sources
Fixed part of one-time capital costs	10.2%	Industry sources
Economic profit	11.1%	MIM est. from financial data
Debt/equity ratio	25%	Public financial data
Markup on typical model:	1.4	Industry sources
Ratio of highest to lowest markup:	0.00	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	8 years	MIM calculation
Percent additional 1-X capital	50%	MIM estimate
Age of replaced capital	6 years	Public financial data

The expenditure schedule above lists the costs incurred over time for preparations to meet the new standards. A percentage of the total cost is attributed to each year before the standards go into effect since that is when these expenses will occur.

C.2 LBL-MIM INPUTS AND OUTPUTS SHOWING THE PRIMARY SCENARIO

Table C.5. Televisions Version of LBL-MIM

Control Panel

TELEVISIONS CONTROL FACTORS	Scenario: Primary		Standard Level = 1		
	Input Value	Cntrl	Vari- ation	Progrm Value	Name
Price Elasticity	-0.600	0.00	100%	-0.600	IPE
Consumer Discount Rate	250.00%	0.00	100%	250.00%	RD
Equity Cost of Capital	0.068	0.00	10%	0.068	ECC
Economic Profit	-0.087	0.00	1%	-0.087	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	FIX
One-Time Capital Costs	0.000	0.00	20%	0.000	CC.N
Unit Variable Cost Increase	\$1.55	0.00	30%	1.548	dVC.N
Elasticity Curve Parameter	0.000	0.00	30%	0.000	ro.N
Short-Run Price Response to Demand	0.157	0.00	76%	0.157	SRPR
SUMMARY	NAECA	NEW	PRVIOUS	NEW	
	BASE	L-RUN	CHANGE	S-RUN	
Shipments	1.19	1.18	-0.28%	-0.28%	1.18
Price	\$219.24	\$220.79	0.71%	0.71%	\$220.70
Revenue (in \$M)	260.05	261.15	0.42%	0.42%	261.11
Net Income	-3.80	-3.83	-0.03	-0.03	-3.90
ROE	-1.92%	-1.94%	-0.02%	-0.02%	-1.98%
13:31		Trys =	2.00		

Table C.6 Televisions Version of LBL-MIM

The Monte Carlo Module

MONTE CARLO DETERMINATION OF STANDARD ERRORS OF ESTIMATES.						
				Secnds/iteration =	1.23	time
				Iterations to go =	0	nn
TELEVISIONS				Sample Size =	40	
	%dQ	%dP	%dR	%dNI	dROE.N	dROE.S
Value	-1.60%	0.43%	-1.18%	-17.72%	-0.15%	-0.32%
Means	-0.35%	0.81%	0.46%	-7.33%	-0.04%	-0.11%
Std. Dev	0.53%	0.42%	0.43%	23.40%	0.11%	0.26%
History	-0.01603	0.004284	-0.01182	-0.17721	-0.00146	-0.00319
...	-0.01167	0.009446	-0.00233	-0.16742	-0.00112	-0.00425
Range	-0.00519	0.008931	0.003699	-0.06201	-0.00035	-0.0004
Name	0.002886	0.006175	0.009079	0.034816	0.000251	0.000285
Is	-0.00046	0.005098	0.00464	0.001168	0.000004	-0.00001
Carlo	-0.00304	0.011009	0.007934	-0.03489	-0.00025	-0.00034
	-0.00857	0.007952	-0.00069	-0.11086	-0.00078	-0.00091
	0.004468	0.005963	0.010458	0.026134	0.000213	0.000593
	-0.0004	0.004083	0.003684	0.061426	0.000302	0.000274
	-0.00157	0.003874	0.002302	-0.01002	-0.00009	-0.001
	-0.01275	0.011491	-0.00141	-0.12862	-0.00072	-0.00269
	-0.00603	0.007579	0.001503	-0.04276	-0.00026	-0.00217
	0.000877	0.006454	0.007337	0.005388	0.000049	0.000142
	-0.00017	0.006914	0.006745	0.000226	-1.2e-06	-5.4e-06
	-0.00253	0.007295	0.00475	-0.03374	-0.00018	-0.00156
	-0.00163	0.005414	0.003777	-0.03214	-0.0002	-0.00101
	-0.00064	0.005858	0.005217	-0.01673	-0.0001	-0.00013
	0.000998	0.01008	0.011088	0.013852	0.000093	0.000334
	-0.00323	0.006531	0.003278	-0.03825	-0.00027	-0.00093
	-0.00231	0.007402	0.005077	-0.0406	-0.00027	-0.00067
	-0.00233	0.005741	0.003395	-0.0027	-0.00007	-0.00024
	-0.00056	0.006969	0.006407	-0.03985	-0.00021	-0.00025
	-0.00607	0.009586	0.003459	-0.10227	-0.00058	-0.00099
	-0.00402	0.009328	0.005273	-0.04675	-0.00031	-0.0029
	-0.00053	0.007913	0.007381	0.056563	0.000275	0.000258
	-0.00217	0.006747	0.004563	-0.03344	-0.00021	-0.00023
	-0.00075	0.008248	0.007494	0.00887	0.000038	0.000035
	-0.00345	0.008893	0.005413	-0.04456	-0.00033	-0.00034
	0.001575	0.006529	0.008114	0.019608	0.000109	0.000182
	-0.00071	0.007302	0.00659	-0.02762	-0.00015	-0.00015
	-0.00754	0.007941	0.000338	-0.13475	-0.00072	-0.001
	-0.00372	0.007295	0.003544	-0.04777	-0.0003	-0.00056
	-0.00157	0.00557	0.003986	-0.06454	-0.0004	-0.00059
	-0.002	0.013311	0.011281	-0.01779	-0.00013	-0.00065

Table C.7. Televisions Version of LBL-MIM

The Accounting Module

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

	1990	BASE '96	NEW '96	CHANGE
Revenue	260.05	260.05	261.15	0.4%
Expenses				
Cost of Goods Sold	185.75	185.75	187.06	0.7%
Selling & G & A	44.82	44.94	44.81	-0.3%
Engineering	5.98	5.99	5.97	-0.3%
Depreciation	28.05	28.05	28.05	NA
1-X Depreciation	0.00	0.00	0.00	NA
Total Expenses	264.60	264.74	265.90	0.4%
Earnings Before Interest & Taxes	-4.55	-4.69	-4.75	1.2%
Interest	1.20	1.07	1.06	-0.4%
Earnings Before Taxes	-5.76	-5.76	-5.81	0.9%
Taxes	-1.96	-1.96	-1.97	0.9%
Net Income	-3.80	-3.80	-3.83	0.9%
Gross Margin	28.57%	28.57%	28.37%	-0.70%
Return on Sales	-1.46%	-1.46%	-1.47%	0.5%
Total Assets	247.30	247.30	246.64	-0.3%
Return on Assets (w/intrst taxed)	-1.22%	-1.25%	-1.27%	0.0
Equity	197.84	197.84	197.31	-0.3%
Return on Equity	-1.92%	-1.92%	-1.94%	0.0

ECONOMIC ANALYSIS

	1989	BASE '96	NEW '96	CHANGE
INCOME				
Shipments	1.19	1.19	1.18	-0.3%
Price	\$219.24	\$219.24	\$220.79	0.7%
Revenue	260.05	260.05	261.15	0.4%
EXPENSE (W/INTEREST)				
Fixed Costs	26.00	26.00	26.00	-9.2%
Variable Costs (w/Q)	239.80	239.80	30.76	-11.5%
Total Expenses	265.80	265.80	56.76	-10.9%
	903	870	776	-10.8%
Inventories	81.61	81.61	81.38	-0.3%
Depreciable	-737.31	-704.31	-610.73	-13.3%
Total Assets	247.30	247.30	246.64	-0.3%

Table C.8 Televisions Version of LBL-MIM

The Engineering Inputs Module

Increment in Additional UVC by Level and Class													
Baseline	0	StdBy	1+ScPow	2+ScPow									
Color	0.0	2.2	1.5	1.6	0	0	0	0	0	0	0	0	0
VCS.E	Additional UVC. (Above Level 0 cost.)												
CLS	0	1	2	3	4	5	6	7	8	9	10	11	12
0.00	0.0	2.2	3.7	5.3	0.0	0	0	0	0	0	0	0	0
KWH.PRINT													
	Kw Hrs /Yr		176	143									
KWS.E	0	1	2	3	4	5	6	7	8	9	10	11	12
Color	205	184	171	139	0	0	0	0	0	0	0	0	0
	Capital cost / unit / 7												
	0	1	2	3	4	5	6	7	8	9	10	11	12
Color	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CC.E	Additional CC. (Above Level 0 cost.)												
CLS	0	1	2	3	4	5	6	7	8	9	10	11	12
0.00	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0	1	2	3	4	5	6	7	8	9	10	11	12
Color	0	0	0	42	0	0	0	0	0	0	0	0	0
CCEE.E	0	0	0	42	0	0	0	0	0	0	0	0	0

Table C.9 Televisions Version of LBL-MIM

The Standards Level Module

Levl _n prev	LEV.B	lev.N	Eng: Levels	0	3	"F _{max}
-1	0	1	REM Levels	-1	3	"S _{max}
1	1	1		1 ==> Stndrds	0 ==> Eng.	
SIE	SIE.B	SIE.N	Esc = QUIT			
VCS.R	Additional UVC by Level and Class. (Above Base cost.)					
LEVEL -->	-1=1990	0=1996	1	2	3	
Color	0.602	0.602	2.15	3.65	5.25	
KWS.R	Kw Hrs /Yr					
LEVEL -->	-1=1990	0=1996	1	2	3	
Color	199	199	184	171	139	
CC.R						
LEVEL -->	-1=1990	0=1996	1	2	3	
Color	0.00	0.00	0.00	0.00	5.00	
CCEE.R						
LEVEL -->	-1=1990	0=1996	1	2	3	
Color	0.00	0.00	0.00	0.00	41.51	
FCA.R and FIX.R						
LEVEL -->	-1=1990	0=1996	1	2	3	
Color	5.16%	5.16%	5.58%	6.00%	40.00%	
Color	1990	1996	NEW96	1990	1996	NEW96
	VC87	VCB	VCN	KW87	KWB	KWN
	0.602	0.602	2.15	199.12	199.12	184
Color	1990	1996	NEW96	Weighted		Weighted
	CPC87	CPCB	CPCN	Op Cost		Fuel Cost
	0.00	0.00	0.00	199.12		F \$17.15
---OUTPUT---						
CC.87	CCB	CCN	CC.B0	CC.N0		
0.00	0.00	0.00	0.00	0.00		

Table C.10 Televisions Version of LBL-MIM

The Costs, Sales, and Revenue Module

COSTS, SALES, and REVENUES							bb	219.24
							aa	0
Ratio of highest to lowest markup:				ratio.0	1.00	ratio.cv	1.00	
Typical markup over UVC				mid.0	0.38	mid.cv	1.00	
Size of firm as % of industry				size.0	0.06			
CALIBRATION CASE (1990)								
	Indst Ship.	Relatv Ship. Q%	Ship. Q.1	Firm Price P.1		Rev. R.1	m.1	UVC.1
Color	21.18	1.00	1.19	219.24		260.05	1.40	156.60
TOTAL S	21.18	20.00%	1.19	\$219		260.05	1.40	20.00%
	"TS.0	"Q.CV	Q.0	P.0		R	"P.CV	UVC
BASE CASE (1996)								
	Change in UVC	Weighted C in UVC	Wghid d P	Pi.B	Op Cost Ratio	Weighted OpCst-R	Qi.B	Ri.B
Color	0.00	0.00	0.00	219.24	1.00	1.00	1.19	260.05
	0.00	0.00	0.00	\$219	260.05	0.00	1.1861	260.05
	Mark.B	dVC.B	Pdiff.B	"P.B	Sum(Ri)	OC%.B0	"Q.B	"R.B
	dVC.B.CV	25.00%			check=R.B			
NEW STANDARDS CASE (1996)								
	Change in UVC	Weighted C in UVC	Wghid d P	Pi.N	% Chng Op Cost	Weighted OpCst-R	Qi.N	Ri.N
Color	1.55	1.55	2.17	\$221	0.92	0.92	1.1828	261.15
TOTAL	0.72	1.55	2.17	\$221	261.15	-0.08	1.1828	261.15
	Mark.N	dVC.N0	Pdiff.N	"P.N	Sum(Ri)	OC%.N0	"Q.N	"R.N
					check=R.N.			

Table C.11 Televisions Version of LBL-MIM

The Financial Module

INPUT	NAME	VALUE	NAME	C.V. or Control Factor
RATES of COST				
After Tax Equity Cost of Capital	ECC.0	0.07	ECC.CV	10%
Interest Rate on Debt	I.0	2.50%	I.CV	100%
Interest Lost on Cash	ICash.0	0.01	ICASH.CV	100%
Rate of Depreciation	Dep.0	0.18		
Tax Rate	T.0	34.00%	T.CV	20%
ASSETS and COSTS as a PERCENT of REVENUE				
Cash	C:R.0	4%	C:R.CV	100.00%
Inventory & Receivables	IR:R.0	31%	IR:R.CV	27.19%
Depreciable Assets	DA:R.0	59%	DA:R.CV	36.89%
G & A	G&A.0	9%	G&A.CV	40.00%
Engineering	Eng	1.20%		
FIXED AND VARIABLE COST SPLIT				
Fixed Part of All Costs & Depr Assets	FDA.0	10.00%	FCA.CV	50.00%
Fixed Part of 1-X Capital Cost	FIX.0	20.00%	FIX.CV	60.00%
OTHER				
Economic Profit	EP.0	-8.72%	EP.CV	1.00%
Debt to Equity ratio	DER.0	25.00%	DER.CV	43.36%
Markup on typical model	"mid	38.00%		
Ratio of highest to lowest markup	"ratio	100.00%		
OUTPUT				
Depreciation	DRR	10.8%		
G&A to Overhead Ratio	G:O	88.2%		
Engineering to Overhead Ratio	E:O	11.8%		
Debt Ratio	DR	20.0%		
Equity Ratio	ER	80.0%		
Pre-Tax Equity Cost of Capital*	PECC	10.3%		
Weighted Average Cost of Capital	WACC	8.7%		
After-Tax WACC	ATWACC	5.8%		
Return on Equity	ROE	-0.019		
Real ROE (Input)	ROE.0	-1.92%		

All interest rates and costs of capital are "real".

*When Pre-Tax ECC is used, all costs are counted tax-exempt.

Table C.12 Televisions Version of LBL-MIM

The One-Time Cost Amortization Module

COSTS AND ASSETS OF ONE-TIME INVESTMENT				
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	5.61%	
Weighted CC Lead-Time Factors	0.00	0.29	0.54	0.26
Cumulative CC Lead-Time Factors		LTC.0	1.092	
$\exp(-ATR*TL)$		EMRT	0.714	
$\exp(-ATR*L)$		EMRL	0.638	
Rate of tax benefit	3.30	BN	0.057	
Remaining tax life		RTL	5.00	years
Tax Benefit Rate: $(1-\%NC)*BN$		BEN	0.028	
Discount factor: $@\exp(-ATR*(L-(TL-RTL)))$		DIS	0.68	
Loss of tax benefit on portion of existing capital with remaining tax life		LEC1	0.124	
Loss of tax benefit on discounted existing capital expenditure in the future		LEC2	0.097	
LEVELIZED CC			GROSS CC	TAX EFF
Initial Cost			1.000	
Tax Benefit of Straight-Line Depreciation				0.289
Savings from not replacing existing Capital later			-0.338	
Loss of Tax Benefit from existing Capital				-0.221
Present Value of CC:			0.662	0.068
Adjusted for Capital Lead Time			0.723	0.074
Levelized Tax Benefit: 1-X dep. of existing Cap.				0.004
LEVELIZED CC FACTOR		CCLF	0.112	0.016
AVERAGE ASSET FACTOR				
Asset Factor for Any New Cap. or Asset		AFB	0.574	
Average Asset Factor for Add-on Capital		AAF	0.287	
INPUT				
NEW CAP. COST: 1990-96 (\$000)	CC.B0	0.00		
1996 CHANGE	CC.N	0.00		
COEFFICIENTS OF VARIATION	CCL.CV	0.20		
OUTPUT				
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.13 Televisions Version of LBL-MIM

The Long-Run Model Module

1990 CASE	A.F	A.Q	A:R	A
Assets -->	0.059	0.892	0.951	247
Costs except taxes	TC.F	TC.Q	TC:R	TC
and equity -->	0.100	0.922	1.022	266
	EC.F	EC.Q	EC:R	EC
Economic costs -->	0.069	0.657	1.066	277
			EI:R	-0.0663
			mul	0.0044
				-228.5
BASE 1996	A.BF	A.BQ		A.B
Assets	15.43	195.48		247.30
	TC.BF	TC.BQ		TC.B
Costs except taxes	26.00	202.17		266
	EC.BF	EC.BQ		EC.B
Economic costs	18.00	144.07		277
NEW 1996	A.NF	A.NQ		A.N
Assets	15.43	195.48		246.64
	TC.NF	TC.NQ		TC.N
Costs except taxes	26.00	203.72		267
	EC.NF	EC.NQ		EC.N
Economic costs	18.00	145.09		278
Assets	-----1990-----	---BASE 1996---	----NEW 1996----	
Shipments	"Q 1.19	Q.B 1.19	Q.N 1.18	
Price	"P \$219.24	P.B \$219.24	P.N \$220.79	
Revenue	"R 260.05	R.B 260.05	R.N 261.15	
Unit Var. Cost	"UVC \$156.60	UVC.B \$156.60	UVC.N \$158.15	
V. Cost Goods Sold	VCGS 185.75	VCGS.B 185.75	VCGS.N 187.06	
1X tax benefit		X1T.B 0.00	X1T.N 0.00	
Pre-tax cost	PTC 265.80	PTC.B 265.80	PTC.N 266.96	
Taxes	TAX -1.96	TAX.B -1.96	TAX.N -1.97	
Net Income	NI -3.80	NI.B -3.80	NI.N -3.83	
Economic Income	EI -17.25	EI.B -17.25	EI.N -17.25	
Equity	EQ 197.84	EQ.B 197.84	EQ.N 197.31	
Retm on Equity	"ROE -1.92%	ROE.B -1.92%	ROE.N -1.94%	

Table C.14 Televisions Version of LBL-MIM

The Short-Run Model Module

Short-Run "Supply Elasticity of Price": (Q/P)*dP/dQ		SRQE.O	0.157
Standard Error of SRQE		SRQE.SD	0.120
Random Value selected for this run:		"SRQE	0.157
R.S	261.11	"P.N	\$220.79
UVC.S	\$158.15	"Q.N	1.18
VCGS.S	187.10		
TC.S	267.02	ap	bp
TAX.S	-2.01	P=a+bQ	186.13
PTC.S	267.02	1.00	cq
NI.S	-3.90	Q=c+dP	1.90
A.S	246.64		0.00
EQ.S	197.31	P.S	220.70
ROE.S	-1.98%	Q.S	1.18
		Check P	\$220.70
		Check Q	1.1831

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.15 Televisions Version of LBL-MIM

The Charts Module

CHARTS OF SENSITIVITY AND PROFIT FOR TELEVISIONS

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

Scenario = Primary

Control Variables		Possible Standards Levels			
Name	Value	Changed	1	2	3
IPE	-0.600	-1.380	-0.03%	-0.06%	-0.26%
RD	250.00%	574.80%	-0.01%	-0.01%	-0.03%
ECC	0.068	0.075	0.00%	0.00%	-0.04%
EP	-0.087	-0.077	0.00%	0.01%	-0.02%
FCA	0.100	0.160	0.01%	0.02%	0.06%
FIX	0.200	0.348	0.00%	0.00%	-0.31%
CC.N	0.000	0.000	0.00%	0.00%	-0.04%
dVC.N	1.548	2.076	-0.01%	-0.02%	-0.04%
ro.N	0.000	0.300	0.00%	0.00%	-0.01%
SRPR	0.157	0.594	0.00	0.00	0.00

Change in Long-Run ROE from 1996 NAECA Base Case by Engineering and Standards Levels

Scenario = Primary

Level	Engin	Standrds
1	-0.03%	-0.02%
2	-0.05%	-0.04%
3	-0.24%	-0.23%

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CHAPTER 1. ENGINEERING ANALYSIS

1.1 INTRODUCTION

A room air conditioner is an encased assembly designed as a unit to be mounted in a window or through a wall. It is designed primarily to provide cool or warm conditioned air to an enclosed space, room, or zone. Heat is sometimes provided by a heat pump operation, electric resistance elements, or by a combination of both.

A room air conditioner consists of refrigerant-side and air-side components all contained within one cabinet. The refrigerant-side components are the evaporator (indoor conditioning coil), the compressor, the condenser (outdoor coil), and the capillary tube. These components are all connected via refrigerant tubing. The air-side components consist of the fan motor, the evaporator fan, and condenser fan. One fan motor is used to drive both fans. The cabinet, which contains these components, is split into an indoor and outdoor side. The two sides are separated by a divider wall, which is usually insulated. The insulation serves to reduce heat transfer between the two sides. The indoor components are the evaporator and evaporator fan. The outdoor components are the compressor, condenser, capillary tube, fan motor, and condenser fan.

A room air conditioner provides conditioned air by drawing warm air from the space or room over the evaporator (indoor coil). In passing over the coil, the air gives up its latent and sensible heat. This conditioned air is then delivered back to the space or room by the evaporator fan. The compressor takes the vaporized refrigerant coming out of the evaporator and raises it to a temperature exceeding that of the outside air. The refrigerant passes on to the condenser (outside coil) where the condenser fan blows outside air over it. The refrigerant gives its heat up to the cooler outside air and condenses. The liquid refrigerant is taken by the capillary tube and its pressure and temperature are reduced. The refrigerant re-enters the evaporator where the refrigeration cycle is repeated.

The present DOE test procedure specifies a steady-state efficiency test to evaluate the efficiency of a room air conditioner. Standard test conditions are defined as 80 °F and 50% relative humidity for the room air and 95 °F and 40% relative humidity for the outdoor air. The DOE test procedure requires that the room air conditioner be operated and tested within a calorimeter room. Specifications for the calorimeter room are detailed in the test procedure (1).

Once test conditions are maintained for at least one hour, data, such as the room air conditioner's cooling capacity and electrical input, are recorded. The energy efficiency ratio (EER), the energy descriptor for room air conditioners, is obtained by dividing the cooling capacity (specified in Btuh) by the electrical input (watts). The annual energy use is determined by multiplying the electrical input measured from the steady-state test by the annual hours of operation. The accepted national average for the annual hours of operation is 750. This value

comes from an analysis the Association of Home Appliance Manufacturers (AHAM) performed to establish the annual hours of operation of a room air conditioner. The results of this study are contained in an appendix to the test method for room air conditioners (2). Since the DOE test procedure is a steady-state test, design options, which can improve the efficiency of the unit on a seasonal basis, cannot be evaluated by it. Other sources of information will be used to evaluate these types of design options.

A large volume room air conditioner manufacturer typically relies on a combination of automated and manual processes in the manufacturing flow. A manufacturing flow diagram is shown in Figure 1.1. Cabinets and heat exchangers are produced in-house. Cabinets are composed out of both sheet metal and plastic components. Cabinet sheet metal is either bought pre-cut to the proper size or cut in-house from large sheet metal rolls. The sheet metal is then manually bent and stamped to form the correct cabinet shape. The plastic component, which consists of the front indoor grill, is either bought from a sub-contractor or molded in house. The heat exchanger is composed of aluminum fins and copper tubing. Aluminum sheets are cut from large rolls and then stamped with the desired fin pattern. Copper tubing is cut from large rolls to the desired tube length. Stamping of the aluminum also includes puncturing it with the desired tube row pattern. The punch press die that is used to cut and stamp the aluminum also automatically stacks the sheets (fins). This stacking process is set up so that the proper amount of fins will be contained in each stack. The copper tubing is then manually shoved through the aluminum fin stack and mechanically expanded within the stack to create a solid contact between the fins and tubes. Return bends are then brazed onto the ends of the copper tubing through either a manual or fully automated process. The completed heat exchanger is tested for leaks before being taken to the assembly line. The assembly of the room air conditioner, taking purchased parts (i.e. compressor, fan motor, fans, controls), the heat exchanger and the cabinet, is done exclusively with manual labor. After being charged with refrigerant, the unit is tested for leaks before being packaged, labeled, and prepared for shipment.

Figure 1.1 Manufacturing Flow Diagram for Room Air Conditioners

1.2 PRODUCT CLASSES

The Department of Energy (DOE) has adopted two new product classes in addition to the twelve product classes specified by NAECA (listed in Table 1.1). The twelve product classes specified by NAECA apply to units that are designed to be installed in double-hung windows and are defined according to the following criteria: capacity, side louvers, and reversing valve. The two new classes are for units that are designed to be installed in casement slider windows and casement only windows. Due to the size constraints imposed by casement windows, casement units are small in size and typically deliver 5,000 to 7,000 Btuh in cooling capacity.

Table 1.1 Product Classes for Room Air Conditioners

Without Reverse Cycle and with Louvered Sides	
1.	Less than 6,000 Btuh
2.	6,000 to 7,999 Btuh
3.	8,000 to 14,000 Btuh
4.	14,000 to 19,999 Btuh
5.	Greater than 20,000 Btuh
Without Reverse Cycle and without Louvered Sides	
6.	Less than 6,000 Btuh
7.	6,000 to 7,999 Btuh
8.	8,000 to 14,000 Btuh
9.	14,000 to 19,999 Btuh
10.	Greater than 20,000 Btuh
11.	With Reverse Cycle and with Louvered Sides
12.	With Reverse Cycle and without Louvered Sides
13.	Casement Slider Units
14.	Casement Only Units

NAECA states that additional classes are warranted for products within a particular class if the products "have a capacity or other performance-related feature that other products within such class do not have and such feature justifies a higher or lower standard from that which applies to other products within such class." When different capacity classes for room air conditioners were established in NAECA, it was assumed that it was justified due to this NAECA provision. Justification was probably based upon the manufacturers need to standardize cabinet production. The reasons for this standardization are based on both economic and installation considerations.

Manufacturers state that every room air conditioner unit could be designed to optimize performance and efficiency as long as a specific cabinet could be built to best suit the unit's particular capacity and efficiency. A room unit's most typical installation is in a double-hung window. Manufacturers cannot afford the luxury of optimizing every model they produce so they limit their production of cabinets to three or four sizes, taking into account the size of the most typical double-hung windows. Each cabinet is designed to accommodate models of the same relative capacity size. Having the same cabinet, these models will tend to have the same design constraints. Since these constraints have a direct impact on efficiency, models of the same relative capacity size will also tend to have the same efficiency. The combined effect of economic and installation constraints results in efficiency being a function of capacity. This effect warrants that the five capacity classes established by NAECA for units without reversing valves be retained.

Additional classes for casement slider and casement only room air conditioners are warranted because they meet the criteria established by NAECA for adopting new product classes. The performance-related feature which they offer, fitting into casement windows, justifies that a lower standard be applied to them. Casement windows impose more severe limitations on room air conditioner size than double-hung windows. Chassis sizes are smaller for casement units resulting in the use of smaller coils. This also limits the flexibility in coil, air handling system, and compressor arrangement. In the case of casement only units, size restrictions are so severe that high-efficiency rotary compressors cannot be used. All these design constraints result in lower system efficiency which necessitates that additional classes be established for casement unit types. Though separate classes are established for casement slider and casement only room air conditioners, no analysis is being performed to determine what type of efficiency standard should be applied to them. The small amount of empirical data received for casement type units prevented any analysis from being performed.

Side louvers have a significant effect on unit performance. Side louvers are stamped on the outdoor sides of the cabinet and enhance the movement of air over the outdoor coil. Units without side louvers operate at a lower efficiency due to the additional compressor power required for compensating for the decreased air flow over the outdoor coil. Units which are intended for installation through a wall require a non-louvered sleeve or a smooth-sided cabinet. By providing consumers with the performance-related feature of wall installation, separate classes become warranted for non-louvered room air conditioners.

Reversing valves allow a room air conditioner to operate as a heat pump and provide space heat in addition to space cooling. The reversing valve adds an additional load to the system that increases the unit's power requirement by an estimated 4%. Because of the additional power requirement and the unique utility of also providing space heat, separate classes are warranted for units using reversing valves.

1.3 DESIGN OPTIONS

The design options are listed in Table 1.2. They are changes that can be incorporated into the design of a room air conditioner to improve its efficiency. Some of the options are found in existing products; others are being developed.

Table 1.2 Design Options for Room Air Conditioners

Increase Heat-Transfer Surface Area	
1.	Increase Frontal Coil Area
2.	Increase Depth of Coil (Add Tube Rows)
3.	Increase Fin Density
4.	Add Subcooler to Condenser Coil
Increase Heat-Transfer Coefficients	
5.	Improve Fin Design
6.	Improve Tube Design
7.	Spray Condensate onto Condenser Coil
8.	Improve Fan and Fan Motor Efficiency
9.	Improve Compressor Efficiency
10.	Variable Speed Compressors
11.	Alternative Refrigerants
12.	Electronic Expansion Valves
13.	Thermostatic Cyclic Controls

As evidenced by the design option table, increasing heat transfer performance can be accomplished by either increasing the heat transfer surface area or the heat transfer coefficients. Design improvements to the heat exchangers are categorized according to these two methods.

As stated in the introduction, design options that are intended to improve efficiency under cycling conditions cannot be evaluated under the steady-state conditions defined by the DOE test procedure. The three design options which improve efficiency solely on a cyclic basis (variable speed compressors, electronic expansion valves, cyclic controls) have been used, not on room units, but on central systems. It has been argued that the operating conditions central systems perform under are very different than those experienced by room units. Room units are generally not used for extended periods of time and when they are turned on, the room temperature is likely to be high, thus reducing the amount of cycling as compared to central systems. Thus, the energy-saving benefits from design options that reduce energy consumption on a cyclic basis are less likely to affect the performance of room units. Before any attempt is made to modify the DOE test procedure to a seasonal rating procedure, thorough field testing must be performed to determine the extent of cycling in room units. Until such testing is performed, estimates of savings due to "cyclic" design options must be extrapolated from their effect on central systems.

Design option effects were quantified by analyzing an actual room air conditioner model for each capacity class defined by NAECA. Several manufacturers provided data on actual room air conditioner models for each of the capacity classes established by NAECA. For each capacity class, a representative unit was chosen from the pool of units that were made available by manufacturers. The analysis performed on this unit established what increase in efficiency could be expected for the entire capacity class. In the process of choosing a representative unit, it became apparent that each manufacturer used a different set of design considerations to develop their models. To attain a certain efficiency rating, one manufacturer might use a high-efficiency compressor with relatively small-sized heat exchangers. Another manufacturer might increase the size of the heat exchangers but retain a low- to mid-efficiency compressor. Thus, the baseline design of the representative unit dictates which design options can be applied to it.

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

Increased Frontal Coil Area

One of the most common ways of increasing heat transfer surface area is by using a coil with a larger frontal area. With a greater amount of coil face area, the heat transfer performance of the coil is increased. In the case of the condenser, more heat can be rejected from the refrigerant to the outside air stream. With regard to the evaporator, more of the room air sensible and latent heat can be used to evaporate the refrigerant. Enhancing the heat-transfer process in either one of the coils results in an increased efficiency for the entire system.

Manufacturers assert that the frontal area of coils in existing room air conditioner chassis designs is so large that any significant increase in system performance requires an increase in the size of the cabinet. This was found to be true in almost all room air conditioner designs. Since the incremental cost of increasing the chassis is relatively significant, manufacturers usually look for other ways to improve system efficiency before attempting to increase the frontal coil area.

Manufacturers provided detailed engineering data for a model in each of the NAECA product classes. This allowed for an appropriate increase in coil frontal area to be selected for each representative baseline unit. For example, in the case of the representative baseline unit chosen for the less than 6,000 Btu/hour product class, the face coil areas were 0.87 and 1.68 square feet for the evaporator and condenser, respectively. Since the manufacturer of this representative baseline unit also provided detailed engineering data on the next largest model, an appropriate increase in coil size could be made. The next largest model has face coil areas of 1.13 and 2.16 square feet for the evaporator and condenser, respectively. These were the face coil areas used for analyzing increases to the coil size for the 6,000 Btu/hour product class. This method of analysis assumes that the chassis size must be enlarged, as the coil sizes in the larger model require more space than what is available in the baseline unit's cabinet.

Increase Depth of Coil

Heat-transfer area can also be increased by adding rows of tubes to the coil. Manufacturers assert that each room air conditioner chassis is designed for a maximum depth evaporator and condenser. Vertical tube rows may be added up to that maximum depth but there is a limit to the number of tube rows that can be added before the chassis size must be increased. Increasing the chassis is a relatively significant cost and could result in prohibiting any tube rows from being added. Besides chassis size, issues of weight, refrigerant charge, and diminishing effectiveness must also be considered.

Manufacturers state that there is a practical limit to the depth of a room air conditioner which is related to weight, appearance, and strength of the mounting. That limit is not well-defined.

With regard to the issue of refrigerant charge, manufacturers point out that the internal volume and, therefore, the amount of refrigerant required, is increased due to the addition of vertical tube rows. To maintain the capacity of the room air unit, the compressor capacity would then have to be reduced. Since the smaller compressor has a lower refrigerant charge limitation, the reliability of the compressor could be sacrificed due to the increased possibility that excess refrigerant could be used by the system.

Manufacturers also assert that each successive row in a coil is only about 70% as effective as the preceding row. The addition of a tube row to a coil already containing three to four rows would probably have small effect on the overall efficiency of the system.

In order to evaluate this design option properly, the detailed engineering data provided by manufacturers included information on how many additional tube rows could be accommodated by each coil without having to enlarge the unit's cabinet. It was assumed that the manufacturer's response accounted for any impacts to compressor reliability.

Increase Fin Density

Increased fin density is still another method for increasing the amount of heat-transfer surface area. Although increasing the fin density improves heat transfer, manufacturers state that its effect on fan power, water drainage, and dirt build-up place a limit on how far the density can be increased.

Fin density has a direct effect on the fan power required to draw or blow air over the coil. Increasing the fin density increases the air-side pressure drop over the coil resulting in more power being used by the fan motor. This reduction in air passage also has the effect of negating some of the improvement in heat transfer that results from increasing the fin density. Increased fin density also causes increased water retention. The condensate that forms on the evaporator and which is slung onto the condenser is not able to drain off as easily. This increases the air-side pressure drop, which results in the effects mentioned above (increased fan power and reduced heat-transfer performance). The build-up of dirt is accelerated by an increase in fin

density. Smaller air passageways through the coils will be more likely to retain dirt. Over the course of a unit's life, performance could actually decrease if the amount of dirt retained is too great.

Obviously, optimizing fin density must take into account all of its resultant effects so as not to put an overall burden on the system. In order to place practical limits on fin density increases, manufacturers suggested fin density maximums for a variety of coils. These fin density maximums are a function of the type of coil (i.e., evaporator, condenser), the fin type (i.e., wavy, louvered, enhanced), the number of tube rows, and the tube diameter. It must be noted these maximums are derived from manufacturer's judgement and not actual tests.

Add Subcooler to Condenser Coil

Typical subcoolers are added between the condenser outlet and the capillary tube inlet and are submerged near the condenser in the condensate produced by the evaporator. The effect of adding a subcooler is to increase the size of the condenser coil as it further cools the refrigerant coming out of the condenser. Because it is relatively difficult to incorporate a subcooler into a room air conditioner, most manufacturers will try to improve the effectiveness of the condenser in other ways before attempting to add one.

Consideration of a subcooler as a design option is directly related to how much space is available in the room air conditioner chassis for its incorporation. If little space is available, the chassis would have to be enlarged to create the necessary room. The cost of adding a subcooler would be significant if enlargement of the chassis were required.

Manufacturers provided the necessary information for evaluating a subcooler as a design option. For the representative units chosen for each class, specifications were given on how large a subcooler could be incorporated into the existing baseline design.

Improve Fin Design

Enhancements to the fin design have the effect of improving the coil's air-side heat-transfer coefficient. This has the effect of improving the overall heat-transfer capability of the coil. This improvement is due in part to the increase of air turbulence over the coil caused by the enhanced fin design. Many manufacturers are using some form of fin enhancement in their coil designs. This fin improvement can be achieved by using a corrugated or wavy fin pattern or a louvered or lanced fin pattern.

Each manufacturer has developed a unique fin design to achieve the desired heat-transfer improvement. Since fin designs are unique for each manufacturer, it is difficult to quantify, in general, the absolute effects of a particular fin enhancement. Research work has been performed in an attempt to develop correlations for the improvement to the air-side heat-transfer coefficient due to a few fin designs (3) (4) (5). Coils used in this research were of the type found in central air conditioners. Because of this, the limitations on the fin enhancement correlations are usually

exceeded when they are applied to room air conditioners. This necessitated a reliance on manufacturer's data to make estimates of what type of enhancement value or factor should be used. Instead of serving as the primary source for estimating fin enhancements, the correlations were used as a check to determine if enhancement factors derived from manufacturer's data were reasonable.

The value used for the fin enhancement factor adjusts the air-side heat-transfer coefficient of the coil. A value of one represents a coil with flat fins and no adjustment is made to the heat-transfer coefficient. Any value greater than one indicates that some enhancement was made to the fins. For example, if the value of the enhancement factor was two, the air-side heat-transfer coefficient would be doubled.

Improve Tube Design

Improvement in the refrigerant-side heat-transfer coefficient is accomplished by augmenting the smooth inside surface of the refrigerant tubes with spiral grooves. This refrigerant tubing is commonly referred to as rifled or grooved tubing. Results from laboratory research indicate that the refrigerant-side heat-transfer coefficient for grooved tubing is significantly greater than that for conventional smooth tubing.

As with fin enhancements, manufacturers of refrigerant tubing have developed various types of grooved tubing to improve the heat-transfer capability of air conditioning coils. Improvement to the refrigerant-side heat-transfer coefficient is a function of the width, height, and spacing of the grooves as well as the concentration of lubricant oil being circulated within the refrigerant. Statistical correlations have been developed to predict what type of enhancement can be expected for both evaporator and condenser coils (6). Since all of this research has been performed under laboratory conditions rather than those that exist for actual room air conditioners, there is some concern as to how applicable this information is to room air conditioners. Because of this concern, room air conditioner manufacturer's data was more heavily relied upon in estimating enhancement factors to the refrigerant-side heat-transfer coefficient due to grooved tubing.

The value used for the tube enhancement factor adjusts the refrigerant-side heat-transfer coefficient of the coil. A value of one represents a coil with smooth tubes and no adjustment is made to the heat-transfer coefficient. Any value greater than one indicates that some enhancement was made to the tubes. For example, if the value of the enhancement factor was two, the refrigerant-side heat-transfer coefficient would be doubled.

Spray Condensate onto Condenser Coil

The condensate that forms on and drips off of the evaporator coil is collected in a condensate pan. The pan is located near the condenser and is placed directly underneath the condenser fan. The condenser fan is equipped with a slinger ring. The slinger ring is located at the fan blade tips and is able to collect and spray small amounts of condensate onto the

condenser coil as the fan rotates. Spraying condensate onto the condenser improves the air-side heat-transfer coefficient of the coil. Spraying condensate onto the condenser coil is such common practice that most, if not all, room air conditioners already incorporate it into their designs.

For the engineering data supplied by manufacturers, all units were found to spray condensate onto their condenser coils. Because of this, condensate spray was not analyzed as a design option to improve room air conditioner efficiency. All representative baseline units included condensate spray in their design. The effect of condensate spray on room air conditioner performance was based upon research to determine the effect that water spray had on heat exchanger performance (7).

Improve Fan and Fan Motor Efficiency

The air delivery system of a room air conditioner consists of one motor driving two fans, the evaporator, and condenser fans. The evaporator fan is usually a blower wheel (centrifugal forward curved fan), the exception being units with capacity less than 6,000 Btuh where propeller type fans are typically used. The condenser fan is a propeller type fan with a slinger ring attached to it. As mentioned earlier, the slinger ring sprays condensate onto the condenser coil. Quantifying the efficiency improvements to the room air conditioner's air delivery system was restricted to analyzing the efficiency improvements to the fan motor only.

Manufacturers state that their fans come from primarily one fan manufacturer leading to standardization of these air system components. Because of this, room air manufacturers are prevented from implementing any individual design improvements to raise the efficiency of their fans. Standardization might serve to explain why data provided by fan manufacturers does not clearly indicate if fan performance can be improved. The fan data was provided in graphical form with brake horsepower as a function of air delivered in cubic feet per minute. Upon inspection of the graphs, it was not apparent if significant reductions in brake horsepower could be accomplished by switching to different fan types. Thus, improving fan efficiency was not analyzed as a design option to improve room air conditioner efficiency.

Air system efficiency can also be improved by reducing the restrictions to air flow. Without making modifications to the heat exchangers, manufacturers state that air flow improvements can only be accomplished by creating more space within the cabinet. This necessitates enlarging the chassis size which, as stated earlier, is costly. In the analysis of increasing the frontal coil area, increases in system efficiency were assumed to be a result not only of the enlarged coil, but also the improvement in air flow due to the larger cabinet. Therefore, improvements in air flow are already inherently considered in the analysis of increased frontal coil areas.

Room air manufacturers maintain that only small improvements in current fan motor technology are possible. Most room air conditioner manufacturers have gone from low-efficiency shaded pole motors to higher efficiency permanent split capacitor (PSC) motors. Depending on the motor size, PSC motors range in efficiency from mid-50% to high-60%. The next significant

jump in efficiency is accomplished by using permanent magnet brushless dc motors. Depending on motor size, brushless dc motors range in efficiency from low-70% to low-80%. Both shaded pole and PSC motors are produced in large quantities, making them relatively inexpensive for room air conditioner manufacturers. Brushless dc motors are a relatively new technology and are relatively more expensive to produce. In addition, their production volumes are very low. This results in a significantly higher cost for brushless dc motors over that of either PSC or shaded pole motors.

Improve Compressor Efficiency

Most room air conditioner manufacturers incorporate rotary compressors into their units. Though current rotary compressors have a maximum efficiency of 11.0 EER, compressor manufacturers are developing new technologies that are allowing them to extend current EER limits.

The "inertia" compressor is a new technology that allows reciprocating compressors to exceed 11.0 EER (8). The compressor's high efficiency is primarily due to the use of responsive light-weight valves and cooler refrigerant gas entering the cylinders because of an innovative approach to refrigerant gas management. The suction gas, which enters the compressor, is directed over the motor end turns and away from the head of the compressor. This prevents the gas from picking up an additional 20° F to 25° F superheat, reducing efficiency losses by up to 4%. Once the gas is in the cylinder, the more responsive valve action results in higher cylinder volumetric efficiencies. "Inertia" compressors are now available for air conditioning systems with capacities exceeding 17,000 Btuh. This new type of reciprocating compressor was analyzed for the two largest capacity classes of room air conditioners.

Scroll compressors are now being produced in large quantities making them accessible for the air conditioning industry. Scroll compressors are an old technology which, until relatively recently, has been difficult to manufacture because of the high precision required to produce its internal components. Advancements in manufacturing processes have allowed for the manufacturing of operational scroll compressors. Those difficulties have been internal leakages and the crank mechanism. As with the new "inertia" compressor, scroll compressors are produced in capacity sizes, which makes them available only to the two largest capacity classes of room air conditioners. Low-capacity scroll compressors exhibit EER ratings that are no better than the highest efficiency rotary compressors currently available. Because of this, scroll compressors were not analyzed as a way to improve compressor efficiency for room air conditioners.

Rotary compressor manufacturers have indicated that "rotary" efficiencies could attain a rating of 12.0 EER within the next three to four years. Although they have not indicated how those efficiency levels could be attained, if rotary compressor development follows the same course in technology advancement as in the past five years, it is realistic to expect that 12.0 EER units could be available for the largest capacity units by the year 1995. It is important to note that no known prototypes have been developed that reach this efficiency level. But because

compressor manufacturers believe that these high-efficiency compressors are within reach, "rotaries" with efficiencies of 11.5 to 12.0 EER were analyzed.

Variable Speed Compressors

Variable speed compressors were developed as a way to better match the load in a room or building. Rather than having only on-off control, modulating the cooling capacity can better match the required load. There are many advantages to variable speed control including quieter operation at low speeds, enhanced comfort by eliminating large fluctuations in room temperature, and improved seasonal energy efficiency.

The control of variable speed compressors is accomplished through the use of electronic adjustable speed drives (ASD) at the motor. Because electronic ASDs are compact and do not have to be mechanically coupled to the motor, they can be easily retrofitted to fractional size horse power motors that are typical of many home appliances, including room air conditioners. Inverter-based ASDs are the most common systems for induction motors while converter-based ASDs are used for permanent magnet brushless dc motors. There are two inverter types that are applicable to room air conditioner compressor (induction) motors: voltage source (VSI) and pulse width modulated voltage source (PWM) inverters. In either inverter case, the input ac power supply is first converted to dc by using a solid-state rectifier. The dc signal is then taken by the inverter to supply a variable-frequency, variable-voltage ac waveform to the motor. The waveform is released in short steps or pulses of power. The speed of the motor will then change in proportion to the frequency.

ASDs have been demonstrated to perform well with both rotary and scroll compressors. The heat pump market in Japan is now dominated by split systems equipped with variable speed rotary compressors. The most common motor used in this application is an induction motor. But the HVAC industry is now showing a strong interest in brushless dc motors due to their high efficiency. Though variable speed technology has yet to be employed by room air conditioners, there seems to be no technological barriers to their implementation.

As discussed earlier, design options that primarily improve efficiency on a seasonal basis will not demonstrate any efficiency improvement according to the steady-state conditions of the DOE test procedure. The greatest benefit of variable speed systems is to save energy on a seasonal basis. Because tests have not been performed to determine the amount of cycling in room air conditioners, it is not clear if seasonal energy savings are available in room air units. Research has demonstrated that energy savings from 15% to 40% are attainable in central systems using variable speed compressors (9) (10) (11). Because room air units do demonstrate some cycling effects, a conservative energy savings estimate of 10% will be applied to room air conditioners that incorporate variable speed compressors.

Alternative Refrigerants

The refrigerant that is used in all room air conditioners is R-22. But because R-22 is a hydrochlorofluorocarbon (HCFC) and demonstrates both ozone depletion potential (ODP) and global-warming potential (GWP), a great deal of research is being performed to find a replacement for it. Both ozone depletion and global warming are world wide concerns and any serious discussion of alternative refrigerants must take these issues into consideration.

In considering energy-efficient replacement refrigerants, a good deal of research has concerned itself with the direct and indirect effects on global warming due to replacement refrigerants. The direct contribution of CFCs to the GWP could be reduced by simply replacing it with a refrigerant with a lower GWP. However, if the replacement refrigerant is less energy-efficient, the indirect contribution to global warming will be increased due to the end-use efficiency change and the associated increased CO₂ emissions. Thus, a lower efficiency replacement refrigerant could actually increase the contributions to global warming even though its direct GWP is lower than that of the refrigerant it is replacing (12).

In addition to ODP, GWP, and energy efficiency, replacement refrigerants must contend with an array of criteria including non-toxicity, non-flammability, and chemical stability and inertness. Research has yet to identify any pure fluid that can be considered a suitable substitute for R-22. Thus, a great deal of attention is being focused on finding binary or ternary replacement mixtures. Non-flammability is a criteria that several promising binary mixtures cannot satisfy. A non-flammable third component could be added suggesting that ternary mixtures can be non-flammable (13). But the resulting ternary mixture is usually less efficient, opening the possibility that its net effect on global warming could be greater than that of R-22.

Some binary and ternary mixtures have demonstrated promise as being suitable substitutes for R-22, but no prototypes have been developed to demonstrate how they might effect the performance of air-conditioning systems. Because of this, alternative refrigerants have not been analyzed as design options for room air conditioners.

Electronic Expansion Valves

The capillary tube is the flow control device that is currently used by all room air conditioners. The capillary tube is a pressure-reducing device that consists of a small diameter line that connects the outlet of the condenser to the inlet of the evaporator. It is designed to provide optimum energy characteristics at one design point. If sized properly, the capillary tube compensates automatically for load and system variations and gives acceptable performance over a wide range of operating conditions. The thermostatic expansion valve (TXV) is another type of flow control device and is commonly used in central air-conditioning systems. It regulates the flow of liquid refrigerant entering the evaporator in response to the superheat of the refrigerant leaving it. TXVs can adapt better to changes in operating conditions such as those due to the variation in ambient temperatures, which effect the condensing temperature. As a result, TXVs can improve the seasonal energy efficiency of air-conditioning equipment.

Electronic expansion valves are similar to thermostatic expansion valves but, since they can be controlled by either digital or electronic circuits, they give the additional flexibility to consider control schemes that are impossible for conventional TXVs. As with TXVs, electronic valves can use the superheat control method to regulate refrigerant flow. Other methods, such as controlling compressor discharge temperature, can also be used. Research has demonstrated that when incorporated into air-conditioning systems using inverter driven variable speed compressors, electronic expansion valves improve seasonal energy efficiency beyond that of systems using conventional TXVs.

As with variable speed compressors, the main benefit of electronic expansion valves is to improve efficiency on a seasonal basis. In addition, no room air conditioner prototypes have been developed using either conventional TXVs or electronic expansion valves. Due to these reasons, expansion valves were not analyzed as design options for room air conditioners.

Thermostatic Cyclic Controls

Remote thermostatic cyclic controls more accurately monitor room temperature than the current built-in thermostats. Research work has been investigating the use of a fuzzy logic controllers for HVAC applications. These controller types have been shown to improve the performance of HVAC systems over that of conventional controllers. Though a remote thermostat, whether it be a conventional or fuzzy type, may offer comfort improvements, efficiency gains would most likely require that it be coupled with an improved air flow discharge and distribution system so as to better mix the room air. Whether or not an improved air-distribution system were required, thermostatic controls would only yield efficiency gains on a seasonal basis.

As with variable speed compressors and expansion valves, the DOE test procedure can only measure energy efficiency improvements based on steady-state conditions. In addition, no data was found or presented that indicated how the performance of room air conditioners could be enhanced with thermostatic cyclic controls. Due to these reasons, thermostatic cyclic controls were not analyzed as a design option for room air conditioners.

1.4 ENERGY USE DATA

Data from room air conditioner manufacturers and the Association of Home Appliance Manufacturers (AHAM) were used to determine representative room air conditioner baseline models for each of the twelve product classes established by NAECA. As stated in the previous section regarding design options, manufacturers and AHAM provided detailed engineering data on actual room air conditioner models for each of the product classes established by NAECA. For the five primary classes (units with side louvers and without a reversing valve), a representative baseline unit was chosen from the pool of units that were made available. Two criteria were used to choose a representative baseline unit: capacity and energy efficiency ratio (EER). The capacity of the unit had to be typical of a majority of the models listed in the 1990 AHAM directory of room air conditioners and the EER had to be close to the minimum allowed

under NAECA in 1990. Figures 1.2 through 1.6 show the distribution of models by efficiency for the five capacity classes with side louvers and without a reversing valve. As evidenced by the figures, most models are manufactured with EERs either at or close to the NAECA minimum. The process for selecting representative baseline units was performed only for the five capacity classes with side louvers and without a reversing valve. According to 1989 room air conditioner domestic shipments data provided by AHAM, over 95% of the units shipped were from these five primary classes (Table 1.3). Baseline units for the other seven classes were derived from those that were selected for the five primary classes. For the five classes without side louvers and without a reversing valve, a 4% power penalty was added to the power calculated for the units with side louvers. For the two classes with a reversing valve, the class with side louvers had a 3% power penalty added to the power calculated for the 14,000 to 20,000 unit while the class without side louvers had a 7% power penalty added to the power calculated for the 8,000 to 14,000 Btuh unit.

Figure 1.2 Distribution of Models by EER: Room Air Conditioners, less than 6,000 Btu/hour

Figure 1.3 Distribution of Models by EER: Room Air Conditioners, 6,000 to 7,999 Btu/hour

Figure 1.4 Distribution of Models by EER: Room Air Conditioners, 8,000 to 13,999 Btu/hour

Figure 1.5 Distribution of Models by EER: Room Air Conditioners, 14,000 to 19,999 Btu/hour

Figure 1.6 Distribution of Models by EER: Room Air Conditioners, greater than 20,000 Btu/hour

Table 1.3 1989 Room Air Conditioner Domestic Shipments

Product Class	% of Total Shipments
Without Reverse Cycle and with Louvers	
Less than 6,000 Btuh	27.7%
6,000 to 7,999 Btuh	17.7%
8,000 to 13,999 Btuh	29.7%
14,000 to 19,999 Btuh	13.2%
Over 20,000 Btuh	7.0%
Without Reverse Cycle and without Louvers	3.2%
With Reverse Cycle and with Louvers	1.5%
With Reverse Cycle and without Louvers	NA

Table 1.4 summarizes some of the important data for the representative baseline units chosen for the five primary room air conditioner product classes. In addition to the data shown in Table 1.4, detailed geometric and refrigeration system information is needed to perform energy-use simulations. These detailed data were provided by room air conditioner manufacturers and AHAM and were used to carry out simulations for each of the twelve product classes. Both rated and measured EERs and capacities are provided in Table 1.4. The rated quantities are those that would be listed in "official" directories and are typical of most models that are produced. The measured quantities represent the EER and capacity of a specific model that has been tested under DOE test conditions. Calibration of the simulation model was based on the measured, rather than the rated quantities. The first section of Appendix A provides a detailed description of the input data for each of the baseline units that were modeled.

Table 1.4 Baseline Room Air Conditioner Characteristics

	EER		Capacity		Evaporator Coil			Condenser Coil			Compressor			Capillary Tube		
Product Class	Rated	Measured	Rated (Btuh)	Measured (Btuh)	Area (sq.ft.)	Fin Design	Tube Design	Area (sq.ft.)	Fin Design	Tube Design	Displc. (cu.in)	EER	Capacity (Btuh)	Number	I.D. (in.)	Length (in.)
Less than 6,000	8.2	8.2	5950	5850	0.87	Wavy	Smooth	1.68	Wavy	Smooth	0.579	10.8	6670	1	0.049	41.5
6,000 to 7,999	8.5	8.45	7550	7480	0.87	Wavy	Smooth	1.68	Wavy	Smooth	0.697	10.9	8100	1	0.054	45
8,000 to 13,999	9	9.3	12000	12155	1.06	Enhance	Smooth	1.81	Enhance	Smooth	1.12	10.3	12780	2	0.049	33
14,000 to 19,999	9	9	17900	17965	1.56	Louver	Grooved	2.54	Louver	Smooth	1.54	10	17540	1	0.075	38
Over 20,000	8.2	8.22	24200	24283	2.04	Louver	Grooved	2.86	Louver	Grooved	2.18	10.61	29400	1	0.09	40

Simulations were carried out using a modified version of the Oak Ridge Heat Pump Design Model, Mark III version (14) (15). The Oak Ridge Model is a comprehensive program for the simulation of an electrically driven, air-source heat pump. It is a steady-state model that is able to calculate the energy efficiency ratio of the equipment being modeled at specified ambient conditions. In the performance evaluation of room air conditioners, the conditions were specified according to those listed in the DOE test procedure. The Mark III version of the Oak Ridge Model is divided into two main parts: the high side and the low side. The high side includes models for the compressor, the condenser, and the expansion device, while the low side contains the evaporator. The model first performs a high-side balance based on calculating a mass flow rate through the flow control device that matches the one determined for the compressor. Once a high-side balance is achieved, a low-side balance is performed in which the evaporator model seeks an air inlet temperature that ensures the previous balance at the high side. This model is insensitive to the amount of refrigerant in the system. Modifications were made to the simulation model in order to simulate the performance of room air conditioners (16). These modifications included the following: addition of routines to model subcoolers and condensate spray, elimination of the reversing valve model, modification of the capillary tube model, and addition of adjustment factors to model grooved tubing.

AHAM reviewed the modified Oak Ridge Model and asserted that additional changes were necessary (17). AHAM requested the following changes: (1) modification of the compressor subroutine to model rotary compressors and better simulate reciprocating compressors, (2) correction of the condensate spray subroutine to better predict its effect on system performance, (3) addition of correction factors to account for indoor/outdoor air leakage, short-circuiting of indoor air, and heat leakage through the divider wall, (4) addition of multiplication factors to modify coil heat-transfer coefficients as a result of using enhanced fin surfaces, (5) addition of correction factors to modify such values as the compressor power and refrigerant mass flow rate in order to assist in calibrating the model to test data, and (6) addition of a psychrometric heat-balance routine to check that the results from the simulation model are thermodynamically consistent. All of these changes, with the exception of adding a psychrometric heat-balance routine, were made to the simulation model. A psychrometric routine was found to be unnecessary as the simulation model was determined to be thermodynamically consistent. Modifications were made to the simulation model to ensure that the condensate spray's effect on exiting condenser air temperature was accounted for. The condensate spray routine itself remained unchanged from the original version. Instead, a condensate spray correction factor was added to the simulation model giving the user the option of adjusting the spray's effect on the condenser's air-side heat-transfer coefficient. Though efforts were made to develop an accurate routine to quantify the effects due to condensate spray, having an accurate method was not crucial since all baseline models already incorporated condensate spray in their designs. The first section of Appendix A contains a more detailed description of the modified Oak Ridge model. Included is a description of the changes made to the simulation model and the input data.

Room air conditioner performance data taken at DOE test conditions were included with the engineering data that was provided by manufacturers and AHAM. This performance data allowed for the calibration of the simulation model to actual test data. For each representative baseline unit chosen, correction factors to adjust the calculated compressor power and refrigerant mass flow rate were used to match the predicted performance of the room air conditioner to that indicated by the test data. In addition to the above correction factors, the length and/or the diameter of the capillary tubes, the compressor shell heat loss, and the evaporator air inlet temperature and humidity were also adjusted to calibrate the model. Though changes to any single input to the model can have repercussions throughout the refrigerant system, adjustments made to the capillary tube, shell heat loss rate, and evaporator air inlet values were done primarily to alter specific system quantities. Capillary tube adjustments were made to change the amount of subcooling. Adjustments to the compressor shell heat loss rate were made to effect high-side refrigerant temperatures. And adjustments to the evaporator air inlet temperature and humidity were made to change system EER and capacity in order to account for discharge air recirculation losses. Values for the percentage of condensate spray that actually reaches the condenser coil before evaporation (PERC) were assumed to be 95% for all representative baseline units. Correction factors for condensate spray effects were not used. Calibrations were conducted on the basis of matching the following "primary" quantities: EER, capacity, and compressor power. Other quantities were also considered in the calibrations. These "secondary" quantities included the following: condensate spray rate, amount of subcooling, evaporator and condenser inlet, outlet, and mid-point (saturation) refrigerant temperatures, compressor inlet and outlet refrigerant temperatures, and capillary tube inlet refrigerant temperature. Although both "primary" and "secondary" quantities were considered, the main objective of the calibration was to have relatively small differences between the measured and simulated results for only the "primary" quantities. Differences between measured and simulated results for the "secondary" quantities were allowed to be larger than for the "primary" quantities.

Table 1.5 presents a comparison between the manufacturers' test data and the data predicted from the simulation model for each of the five primary product classes. Included in the comparison is the percentage difference between the two sets of values.

Table 1.5 Room Air Conditioner Test Data vs. Simulation Model Data

"Primary" and "Secondary" Quantities	Less than 6,000 Btu/h			6,000 to 7,999 Btu/h			8,000 to 13,999 Btu/h			14,000 to 19,999 Btu/h			Over 20,000 Btu/h		
	Test	Model	% Diff	Test	Model	% Diff	Test	Model	% Diff	Test	Model	% Diff	Test	Model	% Diff
EER	8.2	8.3	0.90%	8.5	8.5	0.00%	9.3	9.3	0.30%	9	9	0.00%	8.2	8.3	1.20%
Capacity (Btu/hour)	5850	5869.1	0.30%	7480	7562.2	1.10%	12155	12140.9	-0.10%	17965	18092.1	0.70%	24283	24555	1.10%
Compressor Power (Watts)	585	585	0.00%	753	755	0.30%	1128	1126	-0.20%	1698	1713	0.90%	2579	2579	0.00%
Spray Rate (lbm/hour)	2	2.1	6.10%	2.3	2.6	14.20%	3.9	3.9	-0.80%	5.5	5.9	8.20%	8.5	7.8	-7.70%
Subcooling (°F)	27	23.5	-13.10%	25	23.3	-6.70%	24	19.4	-19.20%	21.4	20	-6.70%	18	16.4	-9.10%
Suction Line Inlet (°F)	57	53	-7.10%	48	42.4	-11.80%	54	43.1	-20.20%	58.4	54.5	-6.70%	61.9	57.6	-6.90%
Compressor Shell Outlet (°F)	172	180.7	5.00%	175	181.9	3.90%	168	180.5	7.40%	182.5	185.9	1.90%	185.7	192.9	3.90%
Condenser Inlet (°F)	-	175.2	-	-	177.7	-	168	177.9	5.90%	181.2	184	1.60%	182	191.3	5.10%
Condenser Outlet (°F)	95	104.8	10.30%	103	100.3	-2.60%	96	101.5	5.70%	102	105.4	3.40%	106.5	104.9	-1.50%
Capillary Tube (°F)	95	101.1	6.40%	102	97.4	-4.50%	-	99.7	-	102	104.3	2.20%	106.5	104	-2.30%
Evaporator Inlet (°F)	-	38.5	-	-	42.5	-	47	39.2	-16.60%	49.3	45.9	-6.90%	44.7	41.7	-6.60%
Evaporator Outlet (°F)	40.3	53	31.50%	43.5	42.4	-2.60%	48	43.1	-10.20%	48.4	54.5	12.60%	47.9	57.6	20.30%
Evaporating (°F)	41	38.5	-6.20%	44.6	42.5	-4.60%	45	39.2	-12.90%	48.8	45.9	-5.90%	43.6	41.7	-4.30%
Condensing (°F)	122	128.3	5.10%	127	123.6	-2.60%	120	120.9	0.70%	123.4	125.4	1.60%	124.5	121.3	-2.60%

With regard to refrigerant temperatures, values are measured and predicted in degrees Fahrenheit. The Fahrenheit scale is not absolute (zero degrees is arbitrarily defined) so it would be unfair to judge the accuracy of the model based on how well it predicted temperatures based on this scale. On the other hand, using an absolute scale measured in degrees Kelvin or Rankine would not be fair either as percentage differences between measured and predicted temperatures would always be relatively small even if Fahrenheit differences exceeded twenty degrees. Though the model's capability at predicting refrigerant temperatures might give some indication of how "good" it is at simulating room air conditioner performance, a better measure would be the model's capability to predict the temperature's effect on the entire system. To do this, test data would also need to provide refrigerant pressures as well as temperatures. With both refrigerant properties, the system's heat removal and heat rejection could be calculated. Comparison of the measured and predicted heat removal and heat rejection would obviously provide a better indication of the model's simulation capabilities. Since test data did not provide refrigerant pressures, the effect that any one temperature had on system performance could not be evaluated.

Another item to consider in comparing measured and predicted refrigerant temperatures is the issue of measurement errors in acquiring test data. The most accurate method of taking refrigerant temperatures would be to immerse sensors directly in the refrigerant flow. With this method, errors would be expected to be small. But if the sensor is attached to the copper tubing, then depending on how well the sensor is secured and insulated, measurement errors could be large. It is believed that the latter method of test measurement was used by manufacturers. In measuring temperatures in this manner, one would expect that measured high-side temperatures would be lower than those predicted by the model and that measured low-side temperatures would be higher. The ambient temperatures have the effect of lowering measured high-side temperatures and raising low-side temperatures. Of the temperature data being analyzed, 80% exhibit this behavior.

The bottom line in evaluating model performance is how accurately it predicts EER and capacity. The calculation of refrigerant temperatures is an intermediary step in determining the efficiency and capacity of the system. The model's capability to predict temperatures should not be viewed as its primary objective. In all capacity classes, both EER and capacity are predicted to within 1.2% of values determined from test measurements.

Using the representative baseline models selected for the five primary product classes, compressor energy use ranged from a minimum of 82.4% to a maximum of 87.3% of the total room air conditioner energy consumption. The rest of the energy use went to drive the fans. These results indicate that the greatest energy conservation opportunity lies with reductions in compressor energy use. This can be accomplished by using more efficient compressors or improving the heat-transfer performance of the evaporator and condenser coils. Of course, since fan motor energy use accounts for at least 12% of the total energy consumption, opportunities for conserving energy are also available by improving the efficiency of the air delivery system and the fan motor.

The results of the simulation analyses for the twelve product classes established by NAECA are shown in Tables 1.6 to 1.17. For each design level, unit capacity, EER, annual hours of operation, and annual energy use are shown. Also included in the tables are total manufacturing costs. These costs will be explained in the next section (Cost-Efficiency Data). The heat-removal capability of the unit is assumed to remain constant regardless of how a particular design option might effect its capacity. Thus, the unit will run a shorter number of hours if a particular design option increases its capacity. For each of the representative baseline units, the annual hours of operation is set to 750 hours. As stated previously, 750 hours is the accepted national average for the annual hours of operation of a room air conditioner. It comes from an analysis AHAM performed to establish its value. The annual heat removal capability of each representative unit is determined by multiplying the baseline capacity by 750 hours. For every design option that is analyzed, the annual hours of operation is determined by taking the calculated heat removal capability and dividing it by its new capacity. Since all design options increase the capacity of the unit, the annual hours of operation will continuously decrease as each new design option is applied. The annual energy use is simply determined by multiplying the total power by the hours of operation.

Table 1.6 Cost-Efficiency Table for Room Air Conditioners Without Reverse Cycle and With Louvered Sides, less than 6,000 Btu/hour

Standard Level	Design	Design Options	Mfg Cost 1990\$	Capacity Btu/h	EER Btu/Watt-hr	Energy Use kWh/yr	Hours hours
1, 2	0	Baseline (1)	179.63	5869.1	8.27	532.1	750.0
	1	0 + Evap/Cond Enhanced Fins (2)	180.44	6102.6	8.78	501.5	721.3
	2	1 + PSC Fan Motor (3)	183.44	6109.4	9.36	470.3	720.5
	3	2 + Evap/Cond Grooved Tubes (4)	186.19	6623.7	9.88	445.7	664.6
	4	3 + Add Subcooler (5)	189.73	6750.2	10.44	421.8	652.1
	5	4 + Incr Compressor EER to 11.0 (6)	191.38	6751.9	10.62	414.6	651.9
	6	5 + Increase Evap/Cond Coil Area (7)	218.13	6935.6	11.05	398.5	634.7
	7	6 + **Variable Speed Compressor (8)	318.13	6935.6	12.27	358.6	634.7
	8	7 + **Brushless D.C. Fan Motor (9)	378.13	6936.8	12.50	352.3	634.6
	9	5 + Incr Compressor EER to 11.5 (10)	203.05	6760.7	11.08	397.3	651.1
	10	9 + Increase Evap/Cond Coil Area (7)	229.87	6936.8	11.52	382.3	634.6
	11	10 + **Variable Speed Compressor (8)	329.87	6936.8	12.79	344.0	634.6
7	12	11 + **Brushless D.C. Fan Motor (9)	389.87	6937.3	13.04	337.7	634.5

** - Design options incorporating Variable Speed Compressors are rated with SEER

NOTES

Efficiency:

- 1 Baseline: Compressor is 6.67 kBTU/h, 10.8 EER; Smooth Refrigerant Tubes; Wavy Fins; Shaded Pole Fan Motor
- 2 Evaporator/Condenser Enhanced Fins: Replace wavy fins with enhanced fins; Evap air-side enhancement=2.18, Cond air-side enhancement=2.14
- 3 PSC Fan Motor: Replace 30% efficiency shaded pole motor with 50% efficiency PSC motor
- 4 Evaporator/Condenser Grooved Tubes: Replace smooth tubes with grooved tubes; Evap refig-side enhancement=2.5, Cond refig-side enhancement=2.0
- 5 Subcooler: Add a subcooler; Length=65", DIA=3/8"
- 6 Increased Compressor Efficiency: Increase from 10.8 EER to 11.0 EER
- 7 Increased Evaporator/Condenser Coil Area: Evap Face Area increased from 0.87 to 1.13 sq.ft., Cond Face Area increased from 1.60 to 2.06 sq.ft.
- 8 Variable Speed Compressor: Replace single-speed compressor with variable-speed compressor
- 9 Brushless D.C. Fan Motor: Replace 50% efficiency PSC motor with 70% efficiency brushless dc motor
- 10 Increased Compressor Efficiency: Increase from 11.0 EER to 11.5 EER

Table 1.7 Cost-Efficiency Table for Room Air Conditioners Without Reverse Cycle and With Louvered Sides, 6,000 to 7,999 Btu/hour

Standard Level	Design	Design Options	Mfg Cost 1990\$	Capacity Btu/h	EER Btu/Watt-hr	Energy Use kWh/yr	Hours hours
	0	Baseline (1)	200.32	7562.2	8.45	670.9	750.0
	1	0 + Evap/Cond Enhanced Fins (2)	201.44	7800.3	8.68	653.8	727.1
1, 2	2	1 + PSC Fan Motor (3)	204.44	7776.8	9.32	608.6	729.3
	3	2 + Add Subcooler (4)	207.98	7855.3	9.59	591.7	722.0
3, 4	4	3 + Evap/Cond Grooved Tubes (5)	212.11	8199.7	9.79	579.5	691.7
	5	4 + Increase Evap/Cond Coil Area (6)	240.18	8348.1	10.24	553.8	679.4
	6	5 + **Variable Speed Compressor (7)	340.18	8348.1	11.38	498.4	679.4
	7	6 + **Brushless D.C. Fan Motor (8)	402.01	8360.8	11.57	490.1	678.4
5	8	4 + Incr Compressor EER to 11.5 (9)	225.67	8203.6	10.25	553.4	691.4
6	9	8 + Increase Evap/Cond Coil Area (6)	254.06	8360.8	10.74	528.3	678.4
	10	9 + **Variable Speed Compressor (7)	354.06	8360.8	11.93	475.5	678.4
7	11	10 + **Brushless D.C. Fan Motor (8)	415.89	8362.8	12.14	467.1	678.2

** - Design options incorporating Variable Speed Compressors are rated with SEER

NOTES

Efficiency:

- 1 Baseline: Compressor is 8.10 kBTU/h, 10.95 EER; Smooth Refrigerant Tubes; Wavy Fins; Shaded Pole Fan Motor
- 2 Evaporator/Condenser Enhanced Fins: Replace wavy fins with enhanced fins; Evap air-side enhancement=1.84, Cond air-side enhancement=1.94
- 3 PSC Fan Motor: Replace 30% efficiency shaded pole motor with 50% efficiency PSC motor
- 4 Subcooler: Add a subcooler to condenser; Length=65", DIA=3/8"
- 5 Evaporator/Condenser Grooved Tubes: Replace smooth tubes with grooved tubes; Evap refig-side enhancement=2.5, Cond refig-side enhancement=2.0
- 6 Increased Evaporator/Condenser Coil Area: Evap Face Area increased from 0.87 to 1.13 sq.ft., Cond Face Area increased from 1.68 to 2.16 sq.ft.
- 7 Variable Speed Compressor: Replace single-speed compressor with variable-speed compressor
- 8 Brushless D.C. Fan Motor: Replace 50% efficiency PSC motor with 70% efficiency brushless dc motor
- 9 Increased Compressor Efficiency: Increase from 10.95 EER to 11.5 BER

Table 1.8 Cost-Efficiency Table for Room Air Conditioners Without Reverse Cycle and With Louvered Sides, 8,000 to 13,999 Btu/hour

Standard Level	Design	Design Options	Mfg Cost 1990\$	Capacity Btu/h	EER Btu/Watt-hr	Energy Use kWh/yr	Hours hours
1	0	Baseline (1)	256.36	12140.9	9.33	976.0	750.0
	1	0 + Add Subcooler (2)	258.30	12316.8	9.71	938.1	739.3
2	2	1 + Incr Compressor EER to 10.7 (3)	262.94	12326.4	10.05	906.4	738.7
3, 4	3	2 + Evap/Cond Grooved Tubes (4)	267.59	13024.0	10.34	880.8	699.1
	4	3 + Increase Evap/Cond Coil Area (5)	297.15	13459.7	11.19	814.1	676.5
	5	4 + **Variable Speed Compressor (6)	397.15	13459.7	12.43	732.7	676.5
	6	5 + **Brushless D.C. Fan Motor (7)	461.73	13462.5	12.60	722.6	676.4
5	7	3 + Incr Compressor EER to 11.5 (8)	288.19	13034.7	11.02	826.2	698.6
6	8	7 + Increase Evap/Cond Coil Area (5)	318.94	13470.5	11.97	760.5	676.0
	9	8 + **Variable Speed Compressor (6)	418.94	13470.5	13.30	684.5	676.0
7	10	9 + **Brushless D.C. Fan Motor (7)	483.52	13473.2	13.50	674.5	675.8

** - Design options incorporating Variable Speed Compressors are rated with SEER

NOTES

Efficiency:

- 1 Baseline: Compressor is 12.78 kBTU/h, 10.3 EER; Smooth Refrigerant Tubes; Enhanced Fins; PSC Fan Motor
- 2 Subcooler: Add a subcooler to condenser; Length=34", DIA=5/16"
- 3 Increased Compressor Efficiency: Increase from 10.3 EER to 10.7 EER
- 4 Evaporator/Condenser Grooved Tubes: Replace smooth tubes with grooved tubes; Evap refig-side enhancement=2.5, Cond refig-side enhancement=2.0
- 5 Increased Evaporator/Condenser Coil Area: Evap Face Area increased from 1.06 to 1.50 sq.ft., Cond Face Area increased from 1.72 to 2.38 sq.ft.
- 6 Variable Speed Compressor: Replace single-speed compressor with variable-speed compressor
- 7 Brushless D.C. Fan Motor: Replace 67% efficiency PSC motor with 80% efficiency brushless dc motor
- 8 Increased Compressor Efficiency: Increase from 10.7 EER to 11.5 EER

Table 1.9 Cost-Efficiency Table for Room Air Conditioners Without Reverse Cycle and With Louvered Sides, 14,000 to 19,999 Btu/hour

Standard Level	Design	Design Options	Mfg Cost 1990\$	Capacity Btu/h	EER Btu/Watt-hr	Energy Use kWh/yr	Hours hours
1	0	Baseline (1)	329.47	18092.1	9.00	1508.0	750.0
	1	0 + Add Subcooler (2)	333.88	18473.2	9.38	1446.4	734.5
2, 3	2	1 + Incr Compressor EER to 10.8 (3)	346.12	18495.8	10.09	1344.7	733.6
4	3	2 + Incr Compressor EER to 11.16 (4)	351.63	18512.4	10.37	1308.7	733.0
	4	3 + **Variable Speed Compressor (5)	451.63	18512.4	11.52	1177.9	733.0
	5	4 + **Increase Evap/Cond Coil Area (6)	542.19	18983.4	12.21	1111.5	714.8
	6	5 + **Brushless D.C. Fan Motor (7)	620.52	18998.1	12.61	1076.4	714.2
	7	2 + Incr Compressor EER to 12.0 (8)	371.73	18518.8	11.04	1229.0	732.7
5, 6	8	7 + Condenser Grooved Tubes (9)	375.85	18619.1	11.13	1218.9	728.8
	9	8 + **Variable Speed Compressor (5)	475.85	18619.1	12.37	1097.0	728.8
	10	9 + **Increase Evap/Cond Coil Area (6)	568.05	19040.8	13.12	1033.9	712.6
7	11	10 + **Brushless D.C. Fan Motor (7)	646.38	19053.6	13.58	998.9	712.2

** - Design options incorporating Variable Speed Compressors are rated with SEER

NOTES

Efficiency:

- 1 Baseline: Compressor is 17.54 kBTu/h, 10.0 EER; Grooved Evaporator Refrigerant Tubes, Enhanced Fins, PSC Fan Motor
- 2 Subcooler: Add a subcooler to condenser; Length=85", DIA=3/8"
- 3 Increased Compressor Efficiency: Increase from 10.0 EER to 10.8 EER
- 4 Increased Compressor Efficiency: Increase from 10.8 EER to 11.16 EER
- 5 Variable Speed Compressor: Replace single-speed compressor with variable-speed compressor
- 6 Increased Evaporator/Condenser Coil Area: Evap Face Area increased from 1.56 to 2.04 sq.ft., Cond Face Area increased from 2.54 to 2.86 sq.ft.
- 7 Brushless D.C. Fan Motor: Replace 59% efficiency PSC motor with 79% efficiency brushless dc motor
- 8 Increased Compressor Efficiency: Increase from 10.80 EER to 12.0 EER
- 9 Condenser Grooved Tubes: Replace smooth tubes with grooved tubes; Cond refig-side enhancement=2.0

Table 1.10 Cost-Efficiency Table for Room Air Conditioners Without Reverse Cycle and With Louvered Sides, greater than 20,000 Btu/hour

Standard Level	Design	Design Options	Mfg Cost 1990\$	Capacity Btu/h	EER Btu/Watt-hr	Energy Use kWh/yr	Hours hours
1, 2, 3	0	Baseline (1)	407.58	24555.0	8.32	2214.8	750.0
	1	0 + Add Subcooler (2)	411.99	24857.4	8.64	2131.0	740.9
	2	1 + Incr Compressor EER to 10.90 (3)	417.53	24862.3	8.85	2081.2	740.7
4	3	2 + Incr Compressor EER to 11.22 (4)	423.65	24867.2	9.08	2028.0	740.6
	4	3 + **Variable Speed Compressor (5)	523.65	24867.2	10.09	1825.2	740.6
	5	4 + **Increase Evap/Cond Coil Area (6)	574.84	25296.8	10.56	1744.5	728.0
	6	5 + **Brushless D.C. Fan Motor (7)	662.34	25304.8	10.74	1715.0	727.8
5	7	2 + Incr Compressor EER to 12.00 (8)	447.92	24878.1	9.63	1912.2	740.3
6	8	7 + **Variable Speed Compressor (5)	547.92	24878.1	10.70	1721.0	740.3
	9	8 + **Increase Evap/Cond Coil Area (6)	601.01	25318.0	11.23	1640.2	727.4
7	10	9 + **Brushless D.C. Fan Motor (7)	688.51	25323.9	11.43	1610.7	727.2

** - Design options incorporating Variable Speed Compressors are rated with SEER

NOTES

Efficiency:

- 1 Baseline: Compressor is 29.4 kBTU/h, 10.61 EER; Grooved Refrigerant Tubes; Enhanced Fins; PSC Fan Motor
- 2 Subcooler: Add a subcooler to condenser; Length=85", DIA=3/8"
- 3 Increased Compressor Efficiency: Increase from 10.61 EER to 10.9 EER
- 4 Increased Compressor Efficiency: Increase from 10.9 EER to 11.22 EER
- 5 Variable Speed Compressor: Replace single-speed compressor with variable-speed compressor
- 6 Increased Evaporator/Condenser Coil Area: Evap Face Area increased from 2.04 to 2.67 sq.ft., Cond Face Area increased from 2.86 to 3.22 sq.ft.
- 7 Brushless D.C. Fan Motor: Replace 66.8% efficiency PSC motor with 80% efficiency brushless dc motor
- 8 Increased Compressor Efficiency: Increased from 10.90 EER to 12.0 EER

Table 1.11 Cost-Efficiency Table for Room Air Conditioners Without Reverse Cycle and Without Louvered Sides, less than 6,000 Btu/hour

Standard Level	Design	Design Options	Mfg Cost 1990\$	Capacity Btu/h	EER Btu/Watt -hr	Energy Use kWh/yr	Hours hours
1, 2	0	Baseline (1)	179.63	5861.6	7.96	552.0	750.0
	1	0 + Evap/Cond Enhanced Fins (2)	180.44	6095.4	8.47	519.2	721.2
	2	1 + PSC Fan Motor (3)	183.44	6102.6	9.01	487.9	720.4
	3	2 + Evap/Cond Grooved Tubes (4)	186.19	6618.9	9.52	461.9	664.2
	4	3 + Add Subcooler (5)	189.73	6747.6	10.06	436.9	651.5
	5	4 + Incr Compressor EER to 11.0 (6)	191.38	6748.4	10.24	429.5	651.4
	6	5 + Increase Evap/Cond Coil Area (7)	218.04	6934.8	10.65	412.9	633.9
	7	6 + **Variable Speed Compressor (8)	318.04	6934.8	11.83	371.6	633.9
	8	7 + **Brushless D.C. Fan Motor (9)	378.04	6935.7	12.04	365.3	633.9
	9	5 + Incr Compressor EER to 11.5 (10)	203.05	6752.8	10.67	412.1	651.0
	10	9 + Increase Evap/Cond Coil Area (7)	229.80	6935.6	11.10	396.1	633.9
	11	10 + **Variable Speed Compressor(8)	329.80	6935.6	12.33	356.5	633.9
7	12	11 + **Brushless D.C. Fan Motor (9)	389.80	6936.3	12.56	350.1	633.8

** - Design options incorporating Variable Speed Compressors are rated with SEER

NOTES

Efficiency:

- 1 Baseline: Compressor is 6.67 kBTU/h, 10.8 EER; Smooth Refrigerant Tubes; Wavy Fins; Shaded Pole Fan Motor
- 2 Evaporator/Condenser Enhanced Fins: Replace wavy fins with enhanced fins; Evap air-side enhancement=2.18, Cond air-side enhancement=2.14
- 3 PSC Fan Motor: Replace 30% efficiency shaded pole motor with 50% efficiency PSC motor
- 4 Evaporator/Condenser Grooved Tubes: Replace smooth tubes with grooved tubes; Evap refig-side enhancement=2.5, Cond refig-side enhancement=2.0
- 5 Subcooler: Add a subcooler; Length=65", DIA=3/8"
- 6 Increased Compressor Efficiency: Increase from 10.8 EER to 11.0 EER
- 7 Increased Evaporator/Condenser Coil Area: Evap Face Area increased from 0.87 to 1.13 sq.ft., Cond Face Area increased from 1.60 to 2.06 sq.ft.
- 8 Variable Speed Compressor: Replace single-speed compressor with variable-speed compressor
- 9 Brushless D.C. Fan Motor: Replace 50% efficiency PSC motor with 70% efficiency brushless dc motor
- 10 Increased Compressor Efficiency: Increase from 11.0 EER to 11.5 EER

Table 1.12 Cost-Efficiency Table for Room Air Conditioners Without Reverse Cycle and Without Louvered Sides, 6,000 to 7,999 Btu/hour

Standard Level	Design	Design Options	Mfg Cost 1990\$	Capacity Btu/h	EER Btu/Watt-hr	Energy Use kWh/yr	Hours hours
1	0	Baseline (1)	200.32	7554.8	8.15	695.0	750.0
	1	0 + Evap/Cond Enhanced Fins (2)	201.44	7731.5	8.37	677.2	732.9
	2	1 + PSC Fan Motor (3)	204.44	7748.9	8.95	633.4	731.2
2	3	2 + Add Subcooler (4)	207.98	7849.0	9.22	614.3	721.9
3, 4	4	3 + Evap/Cond Grooved Tubes (5)	212.11	8196.2	9.43	600.7	691.3
	5	4 + Increase Evap/Cond Coil Area (6)	240.02	8356.3	9.86	574.5	678.1
	6	5 + **Variable Speed Compressor (7)	340.02	8356.3	10.96	517.1	678.1
	7	6 + **Brushless D.C. Fan Motor (8)	401.85	8347.8	11.14	508.8	678.8
5	8	4 + Incr Compressor EER to 11.5 (9)	225.67	8200.4	9.88	573.6	691.0
6	9	8 + Increase Evap/Cond Coil Area (6)	253	8371.6	10.35	547.7	676.8
	10	9 + **Variable Speed Compressor (7)	353.90	8371.6	11.50	492.9	676.8
7	11	10 + **Brushless D.C. Fan Motor (8)	415.73	8360.9	11.69	484.9	677.7

** - Design options incorporating Variable Speed Compressors are rated with SEER

NOTES

Efficiency:

- 1 Baseline: Compressor is 8.10 kBTU/h, 10.95 EER; Smooth Refrigerant Tubes; Wavy Fins; Shaded Pole Fan Motor
- 2 Evaporator/Condenser Enhanced Fins: Replace wavy fins with enhanced fins; Evap air-side enhancement=1.84, Cond air-side enhancement=1.94
- 3 PSC Fan Motor: Replace 30% efficiency shaded pole motor with 50% efficiency PSC motor
- 4 Subcooler: Add a subcooler to condenser; Length=65", DIA=3/8"
- 5 Evaporator/Condenser Grooved Tubes: Replace smooth tubes with grooved tubes; Evap refig-side enhancement=2.5, Cond refig-side enhancement=2.0
- 6 Increased Evaporator/Condenser Coil Area: Evap Face Area increased from 0.87 to 1.13 sq.ft., Cond Face Area increased from 1.68 to 2.16 sq.ft.
- 7 Variable Speed Compressor: Replace single-speed compressor with variable-speed compressor
- 8 Brushless D.C. Fan Motor: Replace 50% efficiency PSC motor with 70% efficiency brushless dc motor
- 9 Increased Compressor Efficiency: Increase from 10.95 EER to 11.5 EER

Table 1.13 Cost-Efficiency Table for Room Air Conditioners Without Reverse Cycle and Without Louvered Sides, 8,000 to 13,999 Btu/hour

Standard Level	Design	Design Options	Mfg Cost 1990\$	Capacity Btu/h	EER Btu/Watt -hr	Energy Use kWh/yr	Hours hours
1	0	Baseline (1)	256.36	12190.2	9.00	1015.7	750.0
	1	0 + Add Subcooler (2)	258.30	12354.4	9.44	968.6	740.0
2	2	1 + Incr Compressor EER to 10.7 (3)	262.94	12313.4	9.69	943.2	742.5
3, 4	3	2 + Evap/Cond Grooved Tubes (4)	267.59	13016.2	9.96	918.1	702.4
	4	3 + Increase Evap/Cond Coil Area (5)	296.80	13454.3	10.78	848.1	679.5
	5	4 + **Variable Speed Compressor (6)	396.80	13454.3	11.98	763.3	679.5
	6	5 + **Brushless D.C. Fan Motor (7)	461.38	13456.4	12.14	753.1	679.4
5	7	3 + Incr Compressor EER to 11.5 (8)	288.19	13029.3	10.65	858.5	701.7
6	8	7 + Increase Evap/Cond Coil Area (5)	318.23	13464.9	11.54	792.1	679.0
	9	8 + **Variable Speed Compressor (6)	418.23	13464.9	12.82	712.9	679.0
7	10	9 + **Brushless D.C. Fan Motor (7)	482.81	13467.3	13.01	702.8	678.9

** - Design options incorporating Variable Speed Compressors are rated with SEER

NOTES

Efficiency:

- 1 Baseline: Compressor is 12.78 kBTU/h, 10.3 EER; Smooth Refrigerant Tubes; Enhanced Fins; PSC Fan Motor
- 2 Subcooler: Add a subcooler to condenser; Length=34", DIA=5/16"
- 3 Increased Compressor Efficiency: Increase from 10.3 EER to 10.7 EER
- 4 Evaporator/Condenser Grooved Tubes: Replace smooth tubes with grooved tubes; Evap refig-side enhancement=2.5, Cond refig-side enhancement=2.0
- 5 Increased Evaporator/Condenser Coil Area: Evap Face Area increased from 1.06 to 1.50 sq.ft., Cond Face Area increased from 1.72 to 2.38 sq.ft.
- 6 Variable Speed Compressor: Replace single-speed compressor with variable-speed compressor
- 7 Brushless D.C. Fan Motor: Replace 67% efficiency PSC motor with 80% efficiency brushless dc motor
- 8 Increased Compressor Efficiency: Increase from 10.7 EER to 11.5 EER

Table 1.14 Cost-Efficiency Table for Room Air Conditioners Without Reverse Cycle and Without Louvered Sides, 14,000 to 19,999 Btu/hour

Standard Level	Design	Design Options		Mfg Cost 1990\$	Capacity Btu/h	EER Btu/Watt-hr	Energy Use kWh/yr	Hours hours
1	0	Baseline	(1)	329.47	18030.9	8.64	1565.9	750.0
	1	0 + Add Subcooler	(2)	333.88	18457.0	9.06	1493.4	732.7
2, 3	2	1 + Incr Compressor EER to 10.8	(3)	346.12	18477.0	9.75	1387.7	731.9
4	3	2 + Incr Compressor EER to 11.16	(4)	351.63	18479.3	10.01	1351.5	731.8
	4	3 + **Variable Speed Compressor	(5)	451.63	18479.3	11.12	1216.4	731.8
	5	4 + **Increase Evap/Cond Coil Area	(6)	540.00	18953.9	11.73	1152.9	713.5
	6	5 + **Brushless D.C. Fan Motor	(7)	618.33	18968.4	12.12	1116.1	712.9
5, 6	7	2 + Incr Compressor EER to 12.0	(8)	371.73	18530.9	10.70	1264.3	729.8
	8	7 + Condenser Grooved Tubes	(9)	375.85	18657.8	10.81	1251.5	724.8
	9	8 + **Variable Speed Compressor	(5)	475.85	18657.8	12.01	1126.3	724.8
	10	9 + **Increase Evap/Cond Coil Area	(6)	565.58	19026.6	12.67	1067.3	710.8
7	11	10 + **Brushless D.C. Fan Motor	(7)	643.91	19037.9	13.10	1032.5	710.3

** - Design options incorporating Variable Speed Compressors are rated with SEER

NOTES

Efficiency:

- 1 Baseline: Compressor is 17.54 kBTU/h, 10.0 EER; Grooved Evaporator Refrigerant Tubes, Enhanced Fins, PSC Fan Motor
- 2 Subcooler: Add a subcooler to condenser; Length=85", DIA=3/8"
- 3 Increased Compressor Efficiency: Increase from 10.0 EER to 10.8 EER
- 4 Increased Compressor Efficiency: Increase from 10.8 EER to 11.16 EER
- 5 Variable Speed Compressor: Replace single-speed compressor with variable-speed compressor
- 6 Increased Evaporator/Condenser Coil Area: Evap Face Area increased from 1.56 to 2.04 sq.ft., Cond Face Area increased from 2.54 to 2.86 sq.ft.
- 7 Brushless D.C. Fan Motor: Replace 59% efficiency PSC motor with 79% efficiency brushless dc motor
- 8 Increased Compressor Efficiency: Increase from 10.80 EER to 12.0 EER
- 9 Condenser Grooved Tubes: Replace smooth tubes with grooved tubes; Cond refig-side enhancement=2.0

Table 1.15 Cost-Efficiency Table for Room Air Conditioners Without Reverse Cycle and Without Louvered Sides, greater than 20,000 Btu/hour

Std. Level	Design	Design Options	Mfg Cost 1990\$	Capacity Btu/h	EER Btu/Watt-hr	Energy Use kWh/yr	Hours hours
1,2,3	0	Baseline (1)	407.58	24540.9	8.03	2293.5	750.0
	1	0 + Add Subcooler (2)	411.99	24851.8	8.34	2205.9	740.6
	2	1 + Incr Compressor EER to 10.90 (3)	417.53	24856.6	8.55	2153.7	740.5
4	3	2 + Incr Compressor EER to 11.22 (4)	423.65	24861.7	8.77	2098.5	740.3
	4	3 + **Variable Speed Compressor (5)	523.65	24861.7	9.75	1888.6	740.3
	5	4 + **Increase Evap/Cond Coil Area (6)	573.57	25286.0	10.18	1808.2	727.9
	6	5 + **Brushless D.C. Fan Motor (7)	661.07	25294.6	10.35	1778.6	727.7
5	7	2 + Incr Compressor EER to 12.00 (8)	447.92	24871.8	9.30	1978.3	740.0
6	8	7 + **Variable Speed Compressor (5)	547.92	24871.8	10.34	1780.4	740.0
	9	8.+ **Increase Evap/Cond Coil Area (6)	599.75	25306.6	10.83	1699.6	727.3
7	10	9 + **Brushless D.C. Fan Motor (7)	687.25	25315.4	11.02	1670.0	727.1

** - Design options incorporating Variable Speed Compressors are rated with SEER

NOTES

Efficiency:

- 1 Baseline: Compressor is 29.4 kBTu/h, 10.61 EER; Grooved Refrigerant Tubes; Enhanced Fins; PSC Fan Motor
- 2 Subcooler: Add a subcooler to condenser; Length=85", DIA=3/8"
- 3 Increased Compressor Efficiency: Increase from 10.61 EER to 10.9 EER
- 4 Increased Compressor Efficiency: Increase from 10.9 EER to 11.22 EER
- 5 Variable Speed Compressor: Replace single-speed compressor with variable-speed compressor
- 6 Increased Evaporator/Condenser Coil Area: Evap Face Area increased from 2.04 to 2.67 sq.ft., Cond Face Area increased from 2.86 to 3.22 sq.ft.
- 7 Brushless D.C. Fan Motor: Replace 66.8% efficiency PSC motor with 80% efficiency brushless dc motor
- 8 Increased Compressor Efficiency: Increased from 10.90 EER to 12.0 EER

Table 1.16 Cost-Efficiency Table for Room Air Conditioners With Reverse Cycle and With Louvered Sides

Std. Level	Design	Design Options		Mfg Cost 1990\$	Capacity Btu/h	EER Btu/Watt-hr	Energy Use kW/h/yr	Hours hours
1	0	Baseline	(1)	329.47	18038.1	8.71	1552.7	750.0
	1	0 + Add Subcooler	(2)	333.88	18459.8	9.16	1477.2	732.9
2,3	2	1 + Incr Compressor EER to 10.8	(3)	346.12	18480.7	9.83	1376.4	732.0
4	3	2 + Incr Compressor EER to 11.16	(4)	351.63	18496.3	10.10	1339.5	731.4
	4	3 + **Variable Speed Compressor	(5)	451.63	18496.3	11.22	1205.5	731.4
	5	4 + **Increase Evap/Cond Coil Area	(6)	540.27	18960.8	11.84	1142.9	713.5
	6	5 + **Brushless D.C. Fan Motor	(7)	618.60	18977.9	12.25	1104.2	712.9
5	7	2 + Incr Compressor EER to 12.0	(8)	571.73	18487.7	10.75	1258.8	731.8
	8	7 + Condenser Grooved Tubes	(9)	375.85	18662.6	10.90	1241.4	724.9
6	9	8 + **Variable Speed Compressor	(5)	475.85	18662.6	12.11	1117.2	724.9
	10	9 + **Increase Evap/Cond Coil Area	(6)	565.86	19031.0	12.78	1058.5	710.9
7	11	10 + **Brushless D.C. Fan Motor	(7)	644.19	19044.8	13.22	1023.6	710.4

** - Design options incorporating Variable Speed Compressors are rated with SEER

NOTES

Efficiency:

- 1 Baseline: Compressor is 17.54 kBTU/h, 10.0 EER; Grooved Evaporator Refrigerant Tubes, Enhanced Fins, PSC Fan Motor
- 2 Subcooler: Add a subcooler to condenser; Length=85", DIA=3/8"
- 3 Increased Compressor Efficiency: Increase from 10.0 EER to 10.8 EER
- 4 Increased Compressor Efficiency: Increase from 10.8 EER to 11.16 EER
- 5 Variable Speed Compressor: Replace single-speed compressor with variable-speed compressor
- 6 Increased Evaporator/Condenser Coil Area: Evap Face Area increased from 1.56 to 2.04 sq.ft., Cond Face Area increased from 2.54 to 2.86 sq.ft.
- 7 Brushless D.C. Fan Motor: Replace 59% efficiency PSC motor with 79% efficiency brushless dc motor
- 8 Increased Compressor Efficiency: Increase from 10.80 EER to 12.0 EER
- 9 Condenser Grooved Tubes: Replace smooth tubes with grooved tubes; Cond refig-side enhancement=2.0

Table 1.17 Cost-Efficiency Table for Room Air Conditioners With Reverse Cycle and Without Louvered Sides

Standard Level	Design	Design Options	Mfg Cost 1990\$	Capacity Btu/h	EER Btu/Watt-hr	Energy Use kWh/yr	Hours hours
1	0	Baseline (1)	256.36	12180.0	8.78	1040.1	750.0
	1	0 + Add Subcooler (2)	258.30	12295.2	9.10	1004.3	743.0
2	2	1 + Incr Compressor EER to 10.7 (3)	262.94	12307.0	9.42	969.6	742.3
3, 4	3	2 + Evap/Cond Grooved Tubes (4)	267.59	13012.2	9.71	940.8	702.0
	4	3 + Increase Evap/Cond Coil Area (5)	296.44	13450.6	10.50	870.3	679.2
	5	4 + **Variable Speed Compressor (6)	396.44	13450.6	11.66	783.3	679.2
	6	5 + **Brushless D.C. Fan Motor (7)	461.02	13476.4	11.75	777.2	677.9
5	7	3 + Incr Compressor EER to 11.5 (8)	288.19	13024.1	10.39	879.6	701.4
6	8	7 + Increase Evap/Cond Coil Area (5)	317.75	13460.1	11.24	812.8	678.7
	9	8 + **Variable Speed Compressor (6)	417.75	13460.1	12.49	731.5	678.7
7	10	9 + **Brushless D.C. Fan Motor (7)	482.33	13462.5	12.66	721.4	678.6

** - Design options incorporating Variable Speed Compressors are rated with SEER

NOTES

Efficiency:

- 1 Baseline: Compressor is 12.78 kBTU/h, 10.3 EER; Smooth Refrigerant Tubes; Enhanced Fins; PSC Fan Motor
- 2 Subcooler: Add a subcooler to condenser; Length=34", DIA=5/16"
- 3 Increased Compressor Efficiency: Increase from 10.3 EER to 10.7 EER
- 4 Evaporator/Condenser Grooved Tubes: Replace smooth tubes with grooved tubes; Evap refig-side enhancement=2.5, Cond refig-side enhancement=2.0
- 5 Increased Evaporator/Condenser Coil Area: Evap Face Area increased from 1.06 to 1.50 sq.ft., Cond Face Area increased from 1.72 to 2.38 sq.ft.
- 6 Variable Speed Compressor: Replace single-speed compressor with variable-speed compressor
- 7 Brushless D.C. Fan Motor: Replace 67% efficiency PSC motor with 80% efficiency brushless dc motor
- 8 Increased Compressor Efficiency: Increase from 10.7 EER to 11.5 EER

For each product class, capacity limits were not considered in the analysis of design options. In the case of the two smallest product classes, the capacity was even allowed to exceed the defined capacity limit. This was done so as not to restrict the number of design options that could be considered for a particular class. Without capacity limits, design options can be applied one after the other with no consideration given to how capacity will be effected. In this way the analysis is not burdened with having to downsize components just for the purpose of keeping the capacity within an artificially defined limit. It was assumed that if room air conditioner manufacturers viewed capacity as a concern, they would be able to design their units to incorporate any design option so that the particular capacity of interest was not exceeded.

Most of the design options in Tables 1.6 to 1.17 are self-explanatory. Notes accompany each design option to explain how it was analyzed. With regard to design options that increase compressor efficiency, only the data for the baseline compressor are from actual compressor performance data. High-efficiency compressor data are derived from the baseline performance data. Compressor performance data provide values of motor input power and refrigerant mass flow rate for a series of evaporating and condensing temperatures. High-efficiency compressor data were derived by simply multiplying the motor input power values for the baseline compressor by the ratio of the baseline and high-efficiency compressor nominal EERs. By analyzing high-efficiency compressors in this manner, increases in system efficiency were ensured of being proportional to increases in compressor efficiency. Use of actual performance data would not only be reflected by changes in motor input power, but also by refrigerant mass flow rate. Changes in both these quantities effects unit capacity, which results in increases or decreases to system efficiency that are beyond those indicated by the increase in EER. Because it was assumed that room air conditioner manufacturers would incorporate a higher efficiency compressor for the sole purpose of increasing its efficiency, derived rather than actual performance data were used.

With the exception of the variable speed compressor design option, energy use for all design option levels was solely determined with the simulation model. Though calibration of the model to actual test data would have been preferred, such data were not available. It is expected that baseline calibrations provide the necessary adjustments to the model so that simulated room air conditioner performance for modified designs would be close to test data if it were made available.

With regard to the variable speed design option, energy use was determined by applying a 10% reduction to the previous design option's energy use. Though variable speed compressors cannot be simulated by the model, energy use estimates for design options that follow the variable speed compressor modification were still based on results from the simulation model. Design options immediately following the variable speed design were applied to the design option immediately preceding the variable speed compressor. In this way, the simulation model could calculate how much energy was saved by the "trailing" design option. The energy use reduction that was calculated was then applied to the variable speed compressor's energy use.

The design options are ordered so that those that are easiest to carry out and that are relatively more cost-effective are listed first. Of the design options listed, only the highest-efficiency compressor (11.5 EER for the three lowest-capacity classes and 12.0 EER for the two largest-capacity classes) is not presently available. This is why there is a branch in the cost-efficiency table at this design option. What results is a primary branch of design options that are all currently available and a secondary branch that incorporates a design that has yet to be developed. As mentioned previously, compressor manufacturers believe that compressor efficiencies of this magnitude will be commercially available within three to four years. So even though a new branch of designs was created, all designs that incorporate these high-efficiency compressors are assumed to be technologically feasible. It is important to note that the efficiency rating for designs incorporating variable speed compressors is a seasonal rating (SEER) rather than a steady-state rating (EER). As stated previously, variable speed designs primarily improve efficiency on a seasonal rather than a steady-state basis.

For all twelve product classes, the energy consumption at the maximum technologically feasible efficiency level can be obtained by the use of brushless dc fan motors. For example, for the less than 6000 Btuh product class with side louvers and without a reversing valve, the minimum technologically feasible energy use is 338 kWh/yr. This unit employs enhanced fins and grooved tubing in both the evaporator and condenser coils, a subcooler, enlarged evaporator and condenser coils, an 11.5 EER variable speed compressor, and a brushless dc fan motor.

1.5 COST-EFFICIENCY DATA

In this section manufacturer cost and energy efficiency data are presented for all twelve product classes. 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 energy efficiency is expressed in EER, except for design options, which incorporate variable speed compressors. Design options incorporating variable speed compressors are rated with SEER.

Most of the cost data are provided by AHAM. AHAM data were collected from several room air conditioner manufacturers and averaged in order to protect the confidentiality of data received from individual manufacturers. Cost data were provided for the following design options: increased rotary compressor efficiency, scroll compressors, increased fin density, increased tube density, grooved tubes, enhanced fins, subcoolers, and increased chassis size (increased coil area). Cost data were not provided for increased fan motor efficiency, improved air mover efficiency, and variable speed compressors. Most of the cost data were expressed as a function of additional material required to incorporate the desired design change. For the increased fin density, increased tube density, and enhanced fin design options, cost was given in terms of dollars per added material volume. For the grooved tube design option, cost was given in terms of dollars per lineal foot of tubing used. For adding a subcooler, cost was a function of subcooler length. Three different "subcooler" functions were provided, each for a different diameter of tubing. Cost data for increasing the efficiency of rotary compressors were given as a function of the rated capacity of the room air conditioner. Cost data for increasing the chassis

size (increasing the coil area) were given as a function of the rated efficiency (EER) of the room air conditioner. For scroll compressors, a specific cost was provided based on a 0.4 EER improvement to the compressor efficiency.

An additional cost of \$100 was assumed for adding a variable speed compressor to a room air conditioner. This was the low value estimated by Whirlpool Corporation in their comments in response to the ANOPR (18).

Fan motor, compressor, and heat exchanger manufacturers also provided cost data. Fan motor manufacturers provided the data necessary for determining the added cost of incorporating PSCs and brushless dc fan motors into room air conditioners. The cost data provided by compressor and heat exchanger manufacturers substantiated the cost estimates made by AHAM for increasing compressor efficiency and improving the performance of heat exchangers. Cost estimates for "inertia" compressors and high-efficiency rotary compressors (11.5 to 12.0 EER) were based on the "AHAM" function for increased rotary compressor efficiency. The function was specified as being valid only for the EER range of 10.3 to 10.9, the approximate efficiency range of rotary compressors currently being manufactured. But since production volumes of "inertia" and high-efficiency rotary compressors are expected to reach the same production levels as rotary compressors currently being manufactured, the "AHAM" function was assumed to be applicable for efficiencies up to 12.0 EER.

The cost and efficiency data were combined and are presented in Tables 1.6 through 1.17. The second section of Appendix A contains disaggregated costs for the five primary product classes. Total costs are divided into variable and capital costs. Variable costs consist of material costs, purchased parts, labor costs, shipping costs, and a portion of indirect costs. Capital costs consist of tooling costs and a portion of indirect costs. Indirect costs include expenses such as general and administrative costs, research and development, rent, utility costs, and certification tests and fees. Since cost data were provided in total cost only, assumptions were made regarding the total cost (in order to determine what percentages were variable) and capital costs. For improved designs requiring the addition of an improved purchased part (i.e., increased compressor or fan motor efficiency), the total cost was assumed to be all variable. For design options requiring changes to components manufactured in-house (i.e., heat exchanger improvements), 85% of the total cost was assumed to be variable and 15% capital. For designs requiring substantial tooling changes (i.e., variable speed compressors and increased coil areas), a split of 60% variable cost and 40% capital cost was assumed. Cost data for the seven non-primary product classes (without side louvers or with a reversing valve) were taken directly from the cost data provided for the five primary classes. The capacity size of the particular non-primary class dictated which primary class cost data were taken from.

1.6 MAXIMUM TECHNOLOGICALLY FEASIBLE DESIGN

As mentioned earlier, the maximum technologically feasible design for all twelve product classes is obtained by the use of brushless dc fan motors. The maximum technologically feasible design also employs enhanced fins and grooved tubing in both the evaporator and condenser

coils, a subcooler, enlarged evaporator and condenser coils, and a high-efficiency (either 11.5 or 12.0 EER) variable speed compressor. The efficiency of the "max tech" design was derived from data given by manufacturers and predicted through the use of the Room Air Conditioner simulation model. All of the efficiency values (and manufacturing costs as well) in Tables 1.6 through 1.17 have some uncertainty associated with them.

For all twelve room air conditioner product classes, the range of the 95% confidence interval for each of the maximum technologically feasible designs is approximately the same. The low end of the interval is, on average, 5.6% lower than the "max tech" design's SEER rating. (The "max tech" design is rated with an SEER because it incorporates a variable speed compressor.) The high end of the interval is, on average, 20.5% higher than the "max tech" design's SEER rating. Volume A, Appendix A, of this Technical Support Document, provides a general discussion of how the 95% confidence interval is established for "max tech" designs.

CHAPTER 2. BASE CASE FORECASTS: ROOM AIR CONDITIONERS

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

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, multifamily, 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 A, Chapter 5.

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. Average lifetimes are 15 years for room air conditioners (Table 2.1).

Table 2.1 Average Equipment Lifetime of Room Air Conditioners

	Years	Source
Room A/C	15.0	LBL

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 room air conditioners

sold in past years are obtained from the trade association, AHAM. The LBL-REM produces projections of annual energy consumption of new appliances after 1989. Table 2.2 shows the trends in efficiency and annual unit energy consumption.

The UEC of new units decreased 23% from 1981 to 1990. The average UEC is projected to decrease 5% from 1990 to 2030.

Table 2.2 Base Case Projection of Unit Energy Consumption for New Room Air Conditioners

Year	Average SEER	UEC (kWh/year)
1981	7.06	1194
1990	9.25	919
1996	9.26	919
2000	9.26	919
2030	9.69	876

Source: AHAM (1980-1989); LBL-REM (1990-2030).

2.3.1.1 Efficiency Distributions

For each class of appliances the range of efficiencies currently available is determined from the AHAM directory. The distribution is presented in Appendix B. In future years, the relative distribution of efficiencies around the projected average is assumed to be similar to the current distribution. Standards diminish the range of available models and alter the shape of the distribution, causing an increase in models at the standard level.

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. Table 2.3 shows that usage is projected to increase 2% from 1981 to 1990, and 12.5% from 1990 to 2030.

Table 2.3 Projected Average Usage of Room Air Conditioners

Year	Usage Factor
1981	0.94
1990	0.96
1996	0.98
2000	1.02
2030	1.08

Source: LBL-REM.

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 LBL-REM. LBL-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 association data) and surveys of appliance ownership (e.g., from DOE/EIA RECS (19) and the Bureau of the Census).

Annual installations of room air conditioners are projected to increase from 3.6 million in 1990 to 5.5 million in 2030. Installations of central air conditioners and heat pumps also increase. Tables 2.4 and 2.5 show the significant trends in the installation and saturation of these products.

Table 2.4 Annual Installations of Air Conditioners in U.S. Households (Thousands)

Year	Room A/C	Central A/C	Heat Pump	Total
1981	2771	1750	301	4822
1990	3664	2368	421	6453
1996	3991	2657	516	7164
2000	4617	2989	552	8159
2030	5517	3955	601	10073

Table 2.5 Percent of Occupied U.S. Housing Units Having Air Conditioners

Year	Room A/C	Central A/C	Heat Pump	Total
1980	31	24	4	59
1990	32	28	6	66
1996	36	29	5	70
2000	38	29	5	72
2030	42	34	5	81

Source: LBL-REM.

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 (engineering estimate), and usage behavior factor.

Table 2.6 shows the U.S. energy consumption, expressed in quadrillion Btu of primary energy using a conversion factor for electricity of one kWh per 11,500 Btu. The projected increase in numbers and usage of room air conditioners overwhelms the decrease in UECs. Energy consumption for room air conditioners increases from 0.48 Quads in 1990 to 0.75 Quads in 2030. Total energy for residential air conditioning increases from 1.37 Quads in 1990 to 1.99 Quads in 2030.

Table 2.6 U.S. Residential Energy Consumption for Air Conditioners (Quadrillion Btu, Primary Energy)

Year	Room A/C	Central A/C	Heat Pump	Total
1981	0.45	0.65	0.12	1.22
1990	0.48	0.74	0.16	1.37
1996	0.53	0.72	0.14	1.39
2000	0.56	0.74	0.14	1.44
2030	0.75	1.06	0.17	1.99

Source: LBL-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 Room Air Conditioners in U.S. Households (1990 dollars)

Year	Room A/C
1981	472
1990	479
1996	479
2000	479
2030	488

Source: LBL-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 1992 to 2030, electricity prices are 3% lower while gas and distillate prices are 5% lower than those in the AEO 1991(20) forecast.
4. *Higher Energy Price.* Assume higher energy prices. Starting from 1992 to 2030, electricity prices are 3% higher while gas and distillate prices are 5% higher than those in the AEO 1991 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 2.8 shows how the average price varies. Tables 2.9 shows 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 2.8 Average Purchase Price of New Room Air Conditioners (1990 Dollars)

Year:	1981	1990	1996	2000	2030
Reference	472	479	479	479	488
1	448	459	460	460	465
2	495	504	504	504	507
3	472	479	479	479	487
4	472	479	479	479	491
5	472	475	503	544	765
6	472	479	488	491	521

Table 2.9 Average Unit Energy Consumption of New Room Air Conditioners (kWh/Year)

Year:	1981	1990	1996	2000	2030
Reference	1194	919	919	919	876
1	1194	904	900	900	868
2	1194	919	919	919	904
3	1194	919	919	919	880
4	1194	919	919	919	868
5	1194	945	839	775	658
6	1194	919	876	868	805.

Source: LBL-REM.

CHAPTER 3. PROJECTED NATIONAL IMPACTS OF STANDARDS: ROOM AIR CONDITIONERS

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

The principal outputs from the LBL-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 trial standards case.

These outputs are provided annually (or for selected years) and cumulatively over a period of time, i.e., 1996-2030. Energy savings are given for each year from implementation of standards to the end of the period. Net present value of the standards 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 trial standards 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. Section 3.5 presents net present value and Section 3.6 discusses the results of the sensitivity analyses.

An overview of the general LBL-REM methodology and demographic assumptions is in Volume A. Product-specific input data are described in this volume, Appendix C.

3.1 STANDARDS LEVELS

Table 3.1 shows the correspondence between the trial standards levels, the engineering design levels, and the associated unit energy consumption.

Table 3.1 Trial Standards Levels for Room Air Conditioners

	Trial Standard Level						
	1	2	3	4	5	6	7
Engineering design option:							
Room A/C up to 6 kBtu with louvres	2	2	4	5	9	10	12
Room A/C up to 6 kBtu w/o louvres	2	2	4	5	9	10	12
Room A/C 6 to 8 kBtu with louvres	2	2	4	4	8	9	11
Room A/C 6 to 8 kBtu w/o louvres	0	3	4	4	8	9	11
Room A/C 8 to 14 kBtu with louvres	0	2	3	3	7	8	10
Room A/C 8 to 14 kBtu w/o louvres	0	2	3	3	7	8	10
Room A/C 14 to 20 kBtu with louvres	0	2	2	3	8	8	11
Room A/C 14 to 20 kBtu without louvres	0	2	2	3	8	8	11
Room A/C over 20 kBtu with louvres	0	0	0	3	7	8	10
Room A/C over 20 kBtu without louvres	0	0	0	3	7	8	10
Heat pump with reversing valve with louvres	0	2	2	3	7	9	11
Heat pump with reversing valve w/o louvres	0	2	3	3	7	8	10
Maximum annual energy consumption (kWh):							
Room A/C up to 6 kBtu with louvres	470	470	422	415	397	382	338
Room A/C up to 6 kBtu w/o louvres	488	488	437	430	412	396	350
Room A/C 6 to 8 kBtu with louvres	609	609	580	580	553	528	467
Room A/C 6 to 8 kBtu w/o louvres	-	614	601	601	574	548	485
Room A/C 8 to 14 kBtu with louvres	-	906	881	881	826	761	675
Room A/C 8 to 14 kBtu w/o louvres	-	943	918	918	859	792	703
Room A/C 14 to 20 kBtu with louvres	-	1345	1345	1309	1219	1219	999
Room A/C 14 to 20 kBtu without louvres	-	1388	1388	1352	1252	1252	1033
Room A/C over 20 kBtu with louvres	-	-	-	2028	1912	1721	1611
Room A/C over 20 kBtu without louvres	-	-	-	2099	1978	1780	1670
Heat pump with reversing valve with louvres	-	1376	1376	1340	1259	1117	1024
Heat pump with reversing valve w/o louvres	-	970	941	941	880	813	721

3.2 ENERGY CONSUMPTION

Table 3.2 shows the past and projected average energy use of new room air conditioners. The weighted average is obtained by taking the product of the UEC for each class times a class-specific weighting factor, then summing over the classes. The weighting factors are:

Room A/C up to 6 kBtu with louvres	.2756
Room A/C up to 6 kBtu without louvres	.0003
Room A/C 6 to 8 kBtu with louvres	.1761
Room A/C 6 to 8 kBtu without louvres	.0070
Room A/C 8 to 14 kBtu with louvres	.2956
Room A/C 8 to 14 kBtu without louvres	.0239
Room A/C 14 to 20 kBtu with louvres	.1313
Room A/C 14 to 20 kBtu without louvres	.0003
Room A/C over 20 kBtu with louvres	.0697

Room A/C over 20 kBtu without louvres	.0003
Heat pump with reversing valve with louvres	.0149
Heat pump with reversing valve without louvres	.0050

The UEC of an average new room air conditioner is projected to remain the same for units bought from 1990 to 1996 in the absence of amended standards.

Table 3.2 Unit Energy Consumption for New Room Air Conditioners (Weighted Average kWh/year)

Year	Base	Trial Standard Level						
		1	2	3	4	5	6	7
1981	1194							
1990	919							
1996	919	908	879	854	839	792	747	658
2000	919	908	879	854	839	792	747	658
2015	919	908	879	854	839	792	747	658
2030	876	872	863	844	835	791	747	658

Source: LBL-REM.

Tables 3.3a to 3.3d present projections of total energy savings for: (a) room air conditioners, (b) central air conditioners, (c) heat pumps (cooling), and (d) total residential air conditioning. Standards (affecting only room air conditioners) are projected to produce cumulative energy savings ranging from 0.28 Quads for standards level 1 to 4.28 Quads for standards level 7, during the period 1996-2030.

Table 3.3a U.S. Electricity Consumption for Room Air Conditioners (Quadrillion Btu, Primary)

Year	Base	Trial Standard Level						
		1	2	3	4	5	6	7
1981	0.447							
1990	0.478							
1996	0.530	0.528	0.526	0.522	0.520	0.515	0.510	0.498
2000	0.558	0.554	0.548	0.538	0.535	0.523	0.510	0.476
2015	0.674	0.664	0.652	0.630	0.625	0.598	0.570	0.499
2030	0.755	0.748	0.740	0.719	0.713	0.683	0.652	0.571
1996-2030	22.80	22.53	22.18	21.56	21.38	20.58	19.74	17.58
Cumulative Savings:		0.28	0.62	1.24	1.42	2.22	3.06	5.22
Percent of Base:		1.2%	2.7%	5.5%	6.2%	9.7%	13.4%	22.9%

Table 3.3b U.S. Electricity Consumption for Central Air Conditioner (not Heat Pump) (Quadrillion Btu, Primary)

Year	Base	Trial Standard Level						
		1	2	3	4	5	6	7
1981	0.655							
1990	0.736							
1996	0.717	0.717	0.717	0.717	0.717	0.717	0.718	0.721
2000	0.735	0.735	0.735	0.735	0.735	0.736	0.738	0.747
2015	0.890	0.890	0.890	0.890	0.890	0.892	0.896	0.920
2030	1.064	1.064	1.064	1.064	1.065	1.067	1.071	1.097
1996-2030	30.67	30.66	30.67	30.67	30.68	30.74	30.86	31.56
Cumulative Savings:		0.01	0.01	0.01	0.00	-0.06	-0.18	-0.88
Percent of Base:		0.0%	0.0%	0.0%	0.0%	-0.2%	-0.6%	-2.9%

Table 3.3c U.S. Electricity Consumption for Heat Pump (Cooling Portion) (Quadrillion Btu, Primary) (Includes Individual Units)

Year	Base	Trial Standard Level						
		1	2	3	4	5	6	7
1981	0.120							
1990	0.159							
1996	0.141	0.141	0.141	0.141	0.141	0.141	0.141	0.141
2000	0.143	0.143	0.143	0.143	0.143	0.143	0.144	0.144
2015	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.161
2030	0.171	0.171	0.171	0.172	0.172	0.172	0.172	0.174
1996-2030	5.49	5.49	5.49	5.49	5.49	5.50	5.51	5.55
Cumulative Savings:		0.00	0.00	-0.01	-0.01	-0.01	-0.02	-0.06
Percent of Base:		0.0%	0.0%	-0.2%	-0.2%	-0.2%	-0.4%	-1.1%

Table 3.3d U.S. Electricity Consumption for Residential Air Conditioning (Quadrillion Btu, Primary)

Year	Base	Trial Standard Level						
		1	2	3	4	5	6	7
1981	1.220							
1990	1.373							
1996	1.388	1.386	1.384	1.380	1.378	1.373	1.369	1.360
2000	1.436	1.432	1.426	1.416	1.413	1.402	1.391	1.367
2015	1.723	1.713	1.699	1.679	1.673	1.649	1.625	1.580
2030	1.990	1.983	1.975	1.955	1.950	1.922	1.895	1.842
1996-2030	58.97	58.68	58.34	57.72	57.56	56.82	56.11	54.69
Cumulative Savings		0.28	0.63	1.25	1.41	2.15	2.86	4.28
Percent of Base		0.5%	1.1%	2.1%	2.4%	3.6%	4.9%	7.3%

Source: LBL-REM.

3.3 ANNUAL INSTALLATIONS

As shown in Table 3.4, installations¹ of cooling equipment are affected by standards. 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 a 2.5% decrease and a 0.6% increase from base for the various standards levels for cumulative shipments of room air conditioners from 1996 to 2030.

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 3.4 Cumulative Installations of Room Air Conditioners (Millions)

1996-2030	Trial Standard Level							
	Base	1	2	3	4	5	6	7
Room AC	171.0	171.3	171.5	171.9	172.0	172.0	171.5	166.7
Central AC	116.0	115.9	116.0	116.0	116.0	116.2	116.7	119.7
Heat Pumps	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.7
TOTAL	306.4	306.7	306.9	307.4	307.5	307.8	307.8	306.2
Change from Base:								
Room AC		0.3	0.5	0.9	1.0	1.0	0.5	-4.3
Central AC		-0.0	0.0	0.0	0.0	0.3	0.8	3.8
Heat Pumps		0.0	0.0	0.0	0.0	0.0	0.1	0.3
TOTAL		0.2	0.5	0.9	1.0	1.3	1.4	-0.3
Percent Change:								
Room AC		0.2%	0.3%	0.5%	0.6%	0.6%	0.3%	-2.5%
Central AC		-0.0%	0.0%	0.0%	0.0%	0.3%	0.7%	3.2%
Heat Pumps		0.0%	0.0%	0.1%	0.1%	0.2%	0.3%	1.3%
TOTAL		0.1%	0.2%	0.3%	0.3%	0.4%	0.5%	-0.1%

Source: LBL-REM.

3.4 APPLIANCE PRICES

Projections of the purchase prices for new room air conditioners in 1990 dollars are shown in Table 3.5. The prices typically increase when standards come into effect.

Table 3.5 Average Purchase Price for New Room Air Conditioner (1990 dollars per unit)

Year	Trial Standard Level							
	Base	1	2	3	4	5	6	7
1981	472							
1990	479							
1996	479	480	485	492	496	521	561	765
2000	479	480	485	492	496	521	561	765
2015	479	481	486	492	496	521	561	765
2030	488	488	490	499	500	522	562	765

3.5 NET PRESENT VALUE

The net present value (NPV) of standards for any product is calculated by first determining the difference in present value of unit life-cycle costs between the base case and standards case each year. That difference is then multiplied by the standards case shipments for the year. The NPV for the period (1996-2030) is the sum over the years of the annual values.

A positive NPV of standards results when the new units in the standards case have lower present value of life-cycle cost than do new units in the base case. Table 3.6 shows the NPV of the trial standards levels.

Table 3.6 Net Present Value to Consumers for Room Air Conditioners Purchased from 1996-2030 (Billion 1990\$ Discounted to 1990 at 7% Real)²

	Trial Standard Level						
	1	2	3	4	5	6	7
Fuel costs savings:							
BENEFIT (energy):	0.49	1.08	2.12	2.40	3.64	4.83	7.26
Equipment costs:							
COST (equipment):	0.04	0.25	0.54	0.72	1.78	3.51	11.96
NET = benefit - cost							
NET PRESENT VALUE:	0.44	0.82	1.59	1.68	1.85	1.32	-4.70
RATIO: benefit/cost							
	10.89	4.26	3.95	3.33	2.04	1.38	0.61

Source: LBL-REM.

3.6 SENSITIVITY ANALYSIS

The base case and standards levels as described above constitute a reference case against which the impacts of standards under different assumptions may be compared. The sensitivity analysis is performed by running the LBL-REM for the base case and trial standards level 5 for room air conditioners. For each sensitivity case, the results for the trial standards level are compared to the corresponding base-case run and the differences are tabulated.

The assumptions in the sensitivity cases are described in Section 2.3 and listed in Table 3.7. Table 3.8 shows results for cumulative energy consumption. The sensitivity analysis of product shipments is given in Table 3.9. Table 3.10 shows the NPVs. The first line of these tables gives the results of the reference case (base case, standards level, and difference). The rest of the lines each give the results corresponding to one of the sensitivity cases, including the base case, standards case, and difference. Note that the changes in the impact of standards as a function of the changed assumptions (difference between the base and standards cases) are the principal results of the sensitivity analysis.

²Normalized to standards case shipments.

Table 3.7 **Sensitivity Analysis Cases**

Case	Description
1	Lower Equipment Prices
2	Higher Equipment Prices
3	Lower Energy Price
4	Higher Energy Price
5	High Equipment Efficiency
6	Market Discount Rates Decline

Table 3.8 **Cumulative Energy Consumption of Room Air Conditioners During the Period 1996-2030 (Quadrillion Btu, Primary)**

	Trial Standard		
	Base	Level 5	Difference
Reference	22.80	20.58	2.22
1	22.46	20.57	1.89
2	22.88	20.56	2.32
3	23.02	20.70	2.32
4	22.55	20.46	2.09
5	18.65	18.01	0.64
6	21.80	20.51	1.29

Table 3.9 **Cumulative Shipments of Room Air Conditioners During the Period 1996-2030 (Millions)**

	Trial Standard		
	Base	Level 5	Difference
Reference	171	172	-1
1	171	172	-1
2	171	172	-1
3	171	172	-1
4	171	172	-1
5	168	168	1
6	172	172	0

Table 3.10 **Total Net Present Value to Consumers for Units Sold during the Period 1996-2030**
(Discounted to 1990 at 4% Real)

Case	Net Present Value (Million \$)
	Trial Standard Level 5
Reference	4271
1	4177
2	4067
3	4305
4	4189
5	1548
6	1832

Source: LBL-REM.

CHAPTER 4. LIFE-CYCLE COSTS AND PAYBACK PERIODS

The effect of standards on individual consumers includes a change in operating expense (usually decreased) and a change in purchase price (usually increased). The net effect is analyzed by calculating the life-cycle cost (LCC), using the engineering data (Chapter 1) for energy consumption and equipment price, and assuming the energy price projected for 1996. Section 4.1 presents the LCC for each design option. The results are displayed as graphs and as tables of values. Sections 4.2 through 4.4 show the impacts of standards on consumers. Section 4.5 presents the effect of different assumptions on the life cycle cost calculations.

The *difference* due to standards is calculated (Sections 4.2 to 4.4) 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 standards. Then only those appliance purchasers who are impacted by standards (i.e., those who would have chosen a design eliminated by standards) are included in calculating the impact of standards on consumers. The impact of standards is expressed by three measures:

- Section 4.2: Payback Period (PBP),
- Section 4.3: Change in Life-Cycle Cost (LCC), and
- Section 4.4: Cost of Conserved Energy (CCE).

4.1 LIFE-CYCLE COST FOR DESIGN OPTIONS

The LCC is the sum of the purchase price (PC) and the operating expense (OC) discounted over the lifetime (N) of the appliance.

$$LCC = PC + \sum_{t=1}^N \frac{OC_t}{(1+r)^t} \quad (1)$$

If operating expenses are constant over time, Eq. 1 simplifies to:

$$LCC = PC + PWF \cdot OC, \quad (2)$$

where we have defined the Present Worth factor:

$$PWF = \sum_{t=1}^N \frac{1}{(1+r)^t} = \frac{1}{r} \left[1 - \frac{1}{(1+r)^N} \right] \quad (3)$$

The LCC is calculated for each class in the year standards are imposed, using a discount rate, r .

4.1.1 LCC Data Inputs

The purchase price is based on the factory costs in the Engineering Analysis (Chapter 1) and includes a factory markup plus distributor and retailer markups, calculated by LBL-MIM. Installation and maintenance costs are also from the Engineering Analysis. Purchase price and installation costs are added to the present value of operating expenses (including maintenance, if applicable), discounted, and summed over the life of the product. Expenses in future years are discounted to the year of purchase, 1996. For the residential sector, the discount rate is 6% real, with sensitivity analysis performed at 2% and 10% real.

The energy price is the projected 1996 average electricity price times an end-use multiplier (see Volume A, Section 5.1.5) of 1.00. Usage conditions are based on the estimated field consumption, namely, 750 hours/year.

4.1.2 LCC Results

Figures 4.1 through 4.12 show the LCCs by design option. The values used to produce these figures are presented in Tables 4.1 to 4.12.

Figure 4.1 Life-Cycle Cost for a Room A/C < 6K Btuh (with side louvers)

Table 4.1 Life-Cycle Costs of Room A/C < 6K Btuh (with side louvers)

Standard Design Level	Design No.	Design Option	Install & Maint	Retail Price	Equipment Price	EER	Annual Energy Use		Annual Energy Cost	Life-Cycle Costs		
							Gas (MMBtu)	Elec (kWh)		4%	6%	10%
	0	Baseline	0.00	287.91	287.91	8.27	0.00	532.1	44.06	777.76	715.81	623.02
1,2	1	0 + Evap/Cond Enhanced Fins	0.00	288.89	288.89	8.78	0.00	501.5	41.52	750.57	692.18	604.73
	2	1 + PSC Fan Motor	0.00	292.68	292.68	9.36	0.00	470.3	38.94	725.64	670.88	588.87
	3	2 + Evap/Cond Grooved Tubes	0.00	296.23	296.23	9.88	0.00	445.7	36.90	706.54	654.65	576.92
3	4	3 + Add Subcooler	0.00	301.55	301.55	10.44	0.00	421.8	34.93	689.86	640.75	567.19
4	5	4 + Increase Comp EER to 11.0	0.00	303.34	303.34	10.62	0.00	414.6	34.33	685.02	636.75	564.45
	6	5 + Increase Evap/Cond Coil Area	0.00	330.33	330.33	11.05	0.00	398.5	33.00	697.19	650.79	581.30
	7	6 + Variable Speed Compressor	0.00	419.65	419.65	12.27	0.00	358.6	29.69	749.78	708.03	645.49
	8	7 + Brushless D.C. Fan Motor	0.00	497.07	497.07	12.50	0.00	352.3	29.17	821.40	780.38	718.94
5	9	5 + Increase Comp EER to 11.5	0.00	320.46	320.46	11.08	0.00	397.3	32.90	686.22	639.96	570.67
6	10	9 + Increase Evap/Cond Coil Area	0.00	342.52	342.52	11.52	0.00	382.3	31.65	694.47	649.96	583.29
	11	10 + Variable Speed Compressor	0.00	430.15	430.15	12.79	0.00	344.0	28.48	746.84	706.79	646.80
7	12	11 + Brushless D.C. Fan Motor	0.00	507.95	507.95	13.04	0.00	337.7	27.96	818.84	779.52	720.63

Notes: This class represents 27.56% of the room air conditioners sold in 1989; average lifetime for all room air conditioners is 15 years; all costs are in 1990 dollars. Electricity rate is 8.28 cent/kWh (1996); installation costs and maintenance costs are not included in the above calculations.

Figure 4.2 Life-Cycle Cost for a Room A/C < 6K Btuh (without side louvers)

Table 4.2 Life-Cycle Costs of Room A/C < 6K Btuh (without side louvers)

Standard Design Level	Design No.	Design Option	Install & Maint	Retail Price	Equipment Price	Annual Energy Use			Annual Energy Cost	Life-Cycle Costs		
						EER	Gas (MMBtu)	Elec (kWh)		4%	6%	10%
	0	Baseline	0.00	287.91	287.91	7.96	0.00	552.0	45.71	796.08	731.81	635.55
	1	0 + Evap/Cond Enhanced Fins	0.00	288.89	288.89	8.47	0.00	519.2	42.99	766.87	706.42	615.87
1,2	2	1 + PSC Fan Motor	0.00	292.68	292.68	9.01	0.00	487.9	40.40	741.84	685.04	599.95
	3	2 + Evap/Cond Grooved Tubes	0.00	296.23	296.23	9.52	0.00	461.9	38.25	721.46	667.68	587.13
3	4	3 + Add Subcooler	0.00	301.55	301.55	10.06	0.00	436.9	36.18	703.76	652.89	576.70
4	5	4 + Increase Comp EER to 11.0	0.00	303.34	303.34	10.24	0.00	429.5	35.56	698.74	648.73	573.83
	6	5 + Increase Evap/Cond Coil Area	0.00	330.28	330.28	10.65	0.00	412.9	34.19	710.40	662.32	590.32
	7	6 + Variable Speed Compressor	0.00	419.62	419.62	11.83	0.00	371.6	30.77	761.72	718.45	653.65
	8	7 + Brushless D.C. Fan Motor	0.00	497.03	497.03	12.04	0.00	365.3	30.25	833.33	790.79	727.09
5	9	5 + Increase Comp EER to 11.5	0.00	320.46	320.46	10.67	0.00	412.1	34.12	699.80	651.86	579.99
6	10	9 + Increase Evap/Cond Coil Area	0.00	342.48	342.48	11.10	0.00	396.1	32.80	707.13	661.01	591.94
	11	10 + Variable Speed Compressor	0.00	430.13	430.13	12.33	0.00	356.5	29.52	758.32	716.82	654.65
7	12	11 + Brushless D.C. Fan Motor	0.00	507.92	507.92	12.56	0.00	350.1	28.99	830.22	789.46	728.41

Notes: This class represents 0.03% of the room air conditioners sold in 1989; average lifetime for all room air conditioners is 15 years; all costs are 1990 dollars; electricity rate is 8.28 cent/kWh (1996); installation costs and maintenance costs are not included in the above calculations.

Figure 4.3 Life-Cycle Cost for a Room A/C 6K to 8K Btuh (with side louvers)

Table 4.3 Life-Cycle Costs of Room A/C 6K to 8K Btuh (with side louvers)

Standard Design Level	Design No.	Design Option	Install & Maint	Retail Price	Equip-ment Price	Annual Energy Use			Annual Energy Cost	Life-Cycle Costs		
						EER	Gas (MMBtu)	Elec (kWh)		4%	6%	10%
1,2	0	Baseline	0.00	396.22	396.22	8.45	0.00	670.9	55.55	1013.85	935.74	818.74
	1	0 + Evap/Cond Enhanced Fins	0.00	398.05	398.05	8.68	0.00	653.8	54.13	999.94	923.82	809.80
	2	1 + PSC Fan Motor	0.00	403.33	403.33	9.32	0.00	608.6	50.39	963.61	892.75	786.62
	3	2 + Add Subcooler	0.00	407.67	407.67	9.59	0.00	591.7	48.99	952.39	883.50	780.31
3,4	4	3 + Evap/Cond Grooved Tubes	0.00	415.53	415.53	9.79	0.00	579.5	47.98	949.02	881.55	780.49
	5	4 + Increase Evap/Cond Coil Area	0.00	450.03	450.03	10.24	0.00	553.8	45.85	959.86	895.38	798.80
	6	5 + Variable Speed Compressor	0.00	560.30	560.30	11.38	0.00	498.4	41.27	1019.13	961.10	874.18
	7	6 + Brushless D.C. Fan Motor	0.00	658.47	658.47	11.57	0.00	490.1	40.58	1109.66	1052.60	967.13
5	8	4 + Increase Comp EER to 11.5	0.00	439.49	439.49	10.25	0.00	553.4	45.82	948.95	884.52	788.01
6	9	8 + Increase Evap/Cond Coil Area	0.00	466.36	466.36	10.74	0.00	528.3	43.74	952.71	891.21	799.07
	10	9 + Variable Speed Compressor	0.00	573.95	573.95	11.93	0.00	475.5	39.37	1011.70	956.33	873.4
7	11	10 + Brushless D.C. Fan Motor	0.00	672.99	672.99	12.14	0.00	467.1	38.68	1103.00	1048.62	967.16

Notes: This class represents 17.61% of the room air conditioners sold in 1989; average lifetime for all room air conditioners is 15 years; all costs are in 1990 dollars; electricity rate is 8.28 cent/kWh (1996); installation costs and maintenance costs are not included in the above calculations.

Figure 4.4 Life-Cycle Cost for a Room A/C 6K to 8K Btuh (without side louvers)

Table 4.4 Life-Cycle Costs of Room A/C 6K to 8K Btuh (without side louvers)

Standard Design Level	Design No.	Design Option	Install & Maint	Retail Price	Equip-ment Price	EER	Annual Energy Use		Annual Energy Cost	Life-Cycle Costs		
							Gas (MMBtu)	Elec (kWh)		4%	6%	10%
1	0	Baseline	0.00	396.22	396.22	8.15	0.00	695.0	57.55	1036.04	955.12	833.92
	1	0 + Evap/Cond Enhanced Fins	0.00	398.05	398.05	8.37	0.00	677.2	56.07	1021.48	942.64	824.54
	2	1 + PSC Fan Motor	0.00	403.33	403.33	8.95	0.00	633.4	52.45	986.44	912.69	802.23
2	3	2 + Add Subcooler	0.00	407.67	407.67	9.22	0.00	614.3	50.86	973.20	901.67	794.55
	3,4	4 3 + Evap/Cond Grooved Tubes	0.00	415.53	415.53	9.43	0.00	600.7	49.74	968.54	898.60	793.84
3,4	5	4 + Increase Evap/Cond Coil Area	0.00	449.92	449.92	9.86	0.00	574.5	47.57	978.81	911.92	811.73
	6	5 + Variable Speed Compressor	0.00	560.24	560.24	10.96	0.00	517.1	42.82	1036.28	976.08	885.90
	7	6 + Brushless D.C. Fan Motor	0.00	658.38	658.38	11.14	0.00	508.8	42.13	1126.78	1067.54	978.81
5	8	4 + Increase Comp EER to 11.5	0.00	439.49	439.49	9.88	0.00	573.6	47.49	967.55	900.76	800.73
6	9	8 + Increase Evap/Cond Coil Area	0.00	466.28	466.28	10.35	0.00	547.7	45.35	970.49	906.73	811.21
	10	9 + Variable Speed Compressor	0.00	573.90	573.90	11.50	0.00	492.9	40.81	1027.66	970.28	884.32
7	11	10 + Brushless D.C. Fan Motor	0.00	672.92	672.92	11.69	0.00	484.9	40.15	1119.32	1062.86	978.30

Notes: This class represents 0.70% of the room air conditioners sold in 1989; average lifetime for all room air conditioners is 15 years; all costs are in 1990 dollars; electricity rate is 8.28 cent/kWh (1996); installation costs and maintenance costs are not included in the above calculations.

Figure 4.5 Life-Cycle Cost for a Room A/C 8K to 14K Btuh (with side louvers)

Table 4.5 Life-Cycle Costs of Room A/C 8K to 14K Btuh (with side louvers)

Standard Design Level	Design No.	Design Option	Install & Maint	Retail Price	Equip-ment Price	EER	Annual Energy Use		Annual Energy Cost	Life-Cycle Costs		
							Gas (MMBtu)	Elec (kWh)		4%	6%	10%
1	0	Baseline	0.00	504.00	504.00	9.33	0.00	976.0	80.81	1402.51	1288.87	1118.67
	1	0 + Add Subcooler	0.00	506.52	506.52	9.71	0.00	938.1	77.67	1370.14	1260.92	1097.32
2	2	1 + Increase Comp EER to 10.7	0.00	514.77	514.77	10.05	0.00	906.4	75.05	1349.20	1243.67	1085.61
3,4	3	2 + Evap/Cond Grooved Tubes	0.00	523.30	523.30	10.34	0.00	880.8	72.93	1334.17	1231.62	1078.01
	4	3 + Increase Evap/Cond Coil Area	0.00	559.40	559.40	11.19	0.00	814.1	67.41	1308.86	1214.08	1072.11
	5	4 + Variable Speed Compressor	0.00	669.58	669.58	12.43	0.00	732.7	60.67	1344.11	1258.80	1131.02
	6	5 + Brushless D.C. Fan Motor	0.00	771.95	771.95	12.60	0.00	722.6	59.83	1437.18	1353.05	1227.03
5	7	3 + Increase Comp EER to 12.0	0.00	556.71	556.71	11.02	0.00	826.2	68.41	1317.31	1221.12	1077.04
6	8	7 + Increase Evap/Cond Coil Area	0.00	616.11	616.11	11.97	0.00	760.5	62.97	1316.23	1227.69	1095.06
	9	8 + Variable Speed Compressor	0.00	695.34	695.34	13.30	0.00	684.5	56.68	1325.49	1245.80	1126.43
7	10	9 + Brushless D.C. Fan Motor	0.00	811.93	811.93	13.50	0.00	674.5	55.85	1432.88	1354.35	1236.72

Notes: This class represents 29.56% of the room air conditioners sold in 1989; average lifetime for all room air conditioners is 15 years; all costs are in 1990 dollars; electricity rate is 8.28 cent/kWh (1996); installation costs and maintenance costs are not included in the above calculations.

Figure 4.6 Life-Cycle Cost for a Room A/C 8K to 14K Btuh (without side louvers)

Table 4.6 Life-Cycle Costs of Room A/C 8K to 14K Btuh (without side louvers)

Standard Design Level	Design No.	Design Option	Install & Maint	Retail Price	Equip-ment Price	Annual Energy Use EER	Annual Energy Use		Annual Energy Cost	Life-Cycle Costs		
							Gas (MMBtu)	Elec (kWh)		4%	6%	10%
1	0	Baseline	0.00	504.00	504.00	9.00	0.00	1015.7	84.10	1439.06	1320.80	1143.67
	1	0 + Add Subcooler	0.00	506.52	506.52	9.44	0.00	968.6	80.20	1398.22	1285.44	1116.53
2	2	1 + Increase Comp EER to 10.7	0.00	514.77	514.77	9.69	0.00	943.2	78.10	1383.08	1273.27	1108.78
3,4	3	2 + Evap/Cond Grooved Tubes	0.00	523.30	523.30	9.96	0.00	918.1	76.02	1368.51	1261.61	1101.50
	4	3 + Increase Evap/Cond Coil Area	0.00	559.19	559.19	10.78	0.00	848.1	70.22	1339.95	1241.21	1093.31
	5	4 + Variable Speed Compressor	0.00	669.48	669.48	11.98	0.00	763.3	63.20	1372.18	1283.31	1150.19
	6	5 + Brushless D.C. Fan Motor	0.00	771.79	771.79	12.14	0.00	753.1	62.36	1465.10	1377.41	1246.08
5	7	3 + Increase Comp EER to 12.0	0.00	556.71	556.71	10.65	0.00	858.5	71.08	1347.05	1247.09	1097.38
6	8	7 + Increase Evap/Cond Coil Area	0.00	614.74	614.74	11.54	0.00	792.1	65.59	1343.95	1251.73	1113.59
	9	8 + Variable Speed Compressor	0.00	695.17	695.17	12.82	0.00	712.9	59.03	1351.47	1268.47	1144.14
7	10	9 + Brushless D.C. Fan Motor	0.00	811.55	811.55	13.01	0.00	702.8	58.19	1458.55	1376.72	1254.16

Notes: This class represents 2.39% of the room air conditioners sold in 1989; a age lifetime for all room air conditioners is 15 years; all costs are in 1995 dollars; electricity rate is 8.28 cent/kWh (1996); installation costs and maintenance costs are not included in the above calculations.

Figure 4.7 Life-Cycle Cost for a Room A/C 14K to 20K Btuh (with side louvers)

Table 4.7 Life-Cycle Costs of Room A/C 14K to 20K Btuh (with side louvers)

Standard Level	Design No.	Design Option	Install & Maint	Retail Price	Equipment Price	EER	Annual Energy Use			Life-Cycle Costs		
							Gas (MMBtu)	Elec (kWh)	Annual Energy Cost	4%	6%	10%
1	0	Baseline	0.00	627.98	627.98	9.00	0.00	1508.0	124.86	2016.25	1840.67	1577.69
	1	0 + Add Subcooler	0.00	635.69	635.69	9.38	0.00	1446.4	119.76	1967.25	1798.85	1546.61
2,3	2	1 + Increase Comp EER to 10.8	0.00	653.19	653.19	10.09	0.00	1344.7	111.34	1891.12	1734.56	1500.06
4	3	2 + Increase Comp EER to 11.16	0.00	669.21	669.21	10.37	0.00	1308.7	108.36	1874.00	1721.63	1493.41
	4	3 + Variable Speed Compressor	0.00	777.58	777.58	11.52	0.00	1177.9	97.53	1861.96	1724.82	1519.40
	5	4 + Increase Evap/Cond Coil Area	0.00	902.22	902.22	12.21	0.00	1111.5	92.03	1925.47	1796.06	1602.22
	6	5 + Brushless D.C. Fan Motor	0.00	974.67	974.67	12.61	0.00	1076.4	89.13	1965.61	1840.28	1652.57
	7	2 + Increase Comp EER to 12.0	0.00	684.85	684.85	11.04	0.00	1229.0	101.76	1816.27	1673.18	1458.85
5,6	8	7 + Condenser Grooved Tubes	0.00	695.90	695.90	11.13	0.00	1218.9	100.92	1818.02	1676.11	1463.54
	9	8 + Variable Speed Compressor	0.00	847.01	847.01	12.37	0.00	1097.0	90.83	1856.91	1729.19	1537.89
	10	9 + Increase Evap/Cond Coil Area	0.00	936.77	936.77	13.12	0.00	1033.9	85.61	1888.58	1768.21	1587.90
7	11	10 + Brushless D.C. Fan Motor	0.00	988.64	988.64	13.58	0.00	998.9	82.71	1908.23	1791.93	1617.73

Notes: This class represents 13.13% of the room air conditioners sold in 1989; average lifetime for all room air conditioners is 15 years; all costs are in 1990 dollars; electricity rate is 8.28 cent/kWh (1996); installation costs and maintenance costs are not included in the above calculations.

Figure 4.8 Life-Cycle Cost for a Room A/C 14K to 20K Btuh (without side louvers)

Table 4.8 Life-Cycle Costs of Room A/C 14K to 20K Btuh (without side louvers)

Standard Level	Design No.	Design Option	Install & Maint	Retail Price	Equipment Price	EER	Annual Energy Use			Life-Cycle Costs		
							Gas (MMBtu)	Elec (kWh)	Annual Energy Cost	4%	6%	10%
1	0	Baseline	0.00	627.98	627.98	8.64	0.00	1565.9	129.66	2069.55	1887.24	1614.16
	1	0 + Add Subcooler	0.00	635.69	635.69	9.06	0.00	1493.4	123.65	2010.52	1836.64	1576.21
2,3	2	1 + Increase Comp EER to 10.8	0.00	653.19	653.19	9.75	0.00	1387.7	114.90	1930.71	1769.14	1527.14
4	3	2 + Increase Comp EER to 11.16	0.00	669.21	669.21	10.01	0.00	1351.5	111.90	1913.40	1756.05	1520.36
	4	3 + Variable Speed Compressor	0.00	777.58	777.58	11.12	0.00	1216.4	100.72	1897.40	1755.78	1543.65
	5	4 + Increase Evap/Cond Coil Area	0.00	901.31	901.31	11.73	0.00	1152.9	95.46	1962.67	1828.44	1627.39
	6	5 + Brushless D.C. Fan Motor	0.00	974.30	974.30	12.12	0.00	1116.1	92.41	2001.78	1871.84	1677.20
	7	2 + Increase Comp EER to 12.0	0.00	684.85	684.85	10.70	0.00	1264.3	104.68	1848.77	1701.57	1481.09
5,6	8	7 + Condenser Grooved Tubes	0.00	695.90	695.90	10.81	0.00	1251.5	103.62	1848.03	1702.32	1484.07
	9	8 + Variable Speed Compressor	0.00	847.01	847.01	12.01	0.00	1126.3	93.26	1883.89	1752.75	1556.34
	10	9 + Increase Evap/Cond Coil Area	0.00	935.77	935.77	12.67	0.00	1067.3	88.37	1918.33	1794.07	1607.94
7	11	10 + Brushless D.C. Fan Motor	0.00	988.50	988.50	13.10	0.00	1032.5	85.49	1939.02	1818.81	1638.75

Notes: This class represents 0.03% of the room air conditioners sold in 1989; average lifetime for all room air conditioners is 15 years; all costs are in 1990 dollars; electricity rate is 8.28 cent/kWh (1996); installation costs and maintenance costs are not included in the above calculations.

Figure 4.9 Life-Cycle Cost for a Room A/C over 20K Btuh (with side louvers)

Table 4.9 Life-Cycle Costs of Room A/C over 20K Btuh (with side louvers)

Standard Design Level	Design No.	Design Option	Install & Maint	Retail Price	Equipment Price	EER	Annual Energy Use			Life-Cycle Costs		
							Gas (MMBtu)	Elec (kWh)	Energy Cost	4%	6%	10%
1,2,3	0	Baseline	0.00	864.79	864.79	8.32	0.00	2214.8	183.39	2903.74	2645.88	2259.63
	1	0 + Add Subcooler	0.00	873.76	873.76	8.64	0.00	2131.0	176.45	2835.56	2587.46	2215.83
	2	1 + Increase Comp EER to 10.9	0.00	885.53	885.53	8.85	0.00	2081.2	172.32	2801.49	2559.18	2196.24
4	3	2 + Increase Comp EER to 11.22	0.00	898.51	898.51	9.08	0.00	2028.0	167.92	2765.49	2529.38	2175.71
	4	3 + Variable Speed Compressor	0.00	1031.65	1031.65	10.09	0.00	1825.2	151.13	2711.93	2499.43	2181.13
	5	4 + Increase Evap/Cond Coil Area	0.00	1086.45	1086.45	10.56	0.00	1744.5	144.44	2692.44	2489.33	2185.10
5	6	5 + Brushless D.C. Fan Motor	0.00	1219.55	1219.55	10.74	0.00	1715.0	142.00	2798.38	2598.71	2299.63
	7	2 + Increase Comp EER to 12.0	0.00	928.38	928.38	9.63	0.00	1912.2	158.33	2688.76	2466.12	2132.65
	8	7 + Variable Speed Compressor	0.00	1046.22	1046.22	10.70	0.00	1721.0	142.50	2630.58	2430.20	2130.08
6	9	8 + Increase Evap/Cond Coil Area	0.00	1159.16	1159.16	11.23	0.00	1640.2	135.81	2669.13	2478.17	2192.13
	10	9 + Brushless D.C. Fan Motor	0.00	1252.32	1252.32	11.43	0.00	1610.7	133.37	2735.13	2547.60	2266.71

Notes: This class represents 6.97% of the room air conditioners sold in 1989; average lifetime for all room air conditioners is 15 years; all costs are in 1990 dollars; electricity rate is 8.28 cent/kWh (1996); installation costs and maintenance costs are not included in the above calculations.

Figure 4.10 Life-Cycle Cost for a Room A/C over 20K Btuh (without side louvers)

Table 4.10 Life-Cycle Costs of Room A/C over 20K Btuh (without side louvers)

Standard Design Level	Design No.	Design Option	Install & Maint	Retail Price	Equipment Price	EER	Annual Energy Use			Life-Cycle Costs		
							Gas (MMBtu)	Elec (kWh)	Annual Energy Cost	4%	6%	10%
1,2,3	0	Baseline	0.00	845.25	845.25	8.03	0.00	2293.5	189.90	2956.65	2689.62	2289.66
	1	0 + Add Subcooler	0.00	854.02	854.02	8.34	0.00	2205.9	182.65	2884.78	2627.95	2243.26
	2	1 + Increase Comp EER to 10.9	0.00	865.51	865.51	8.55	0.00	2153.7	178.33	2848.21	2597.46	2221.87
4	3	2 + Increase Comp EER to 11.22	0.00	878.20	878.20	8.77	0.00	2098.5	173.76	2810.08	2565.76	2199.80
	4	3 + Variable Speed Compressor	0.00	1008.34	1008.34	9.75	0.00	1888.6	156.38	2746.99	2527.10	2197.75
	5	4 + Increase Evap/Cond Coil Area	0.00	1061.10	1061.10	10.18	0.00	1808.2	149.72	2725.74	2515.21	2199.88
5	6	5 + Brushless D.C. Fan Motor	0.00	1191.82	1191.82	10.35	0.00	1778.6	147.27	2829.20	2622.12	2311.95
	7	2 + Increase Comp EER to 12.0	0.00	907.40	907.40	9.30	0.00	1978.3	163.80	2728.63	2498.30	2153.30
	8	7 + Variable Speed Compressor	0.00	1022.58	1022.58	10.34	0.00	1780.4	147.42	2661.62	2454.33	2143.85
6	9	8 + Increase Evap/Cond Coil Area	0.00	1132.41	1132.41	10.83	0.00	1699.6	140.73	2697.07	2499.18	2202.79
	10	9 + Brushless D.C. Fan Motor	0.00	1223.89	1223.89	11.02	0.00	1670.0	138.28	2761.30	2566.86	2275.63

Notes: This class represents 0.03% of the room air conditioners sold in 1989; average lifetime for all room air conditioners is 15 years; all costs at 1990 dollars; electricity rate is 8.28 cent/kWh (1996); installation costs and maintenance costs are not included in the above calculations.

Figure 4.11 Life-Cycle Cost for a Room A/C with Reversing Valve (with side louvers)

Table 4.11 Life-Cycle Costs of Room A/C with Reversing Valve (with side louvers)

Standard Design Level	Design No.	Design Option	Install & Maint	Retail Price	Equipment Price	EER	Annual Energy Use		Annual Energy Cost	Life-Cycle Costs		
							Gas (MMBtu)	Elec (kWh)		4%	6%	10%
1	0	Baseline	0.00	801.76	801.76	8.71	0.00	1552.7	128.56	2231.18	2050.40	1779.62
	1	0 + Add Subcooler	0.00	811.61	811.61	9.16	0.00	1477.2	122.31	2171.52	1999.54	1741.93
2,3	2	1 + Increase Comp EER to 10.8	0.00	833.94	833.94	9.83	0.00	1376.4	113.97	2101.06	1940.81	1700.77
4	3	2 + Increase Comp EER to 11.16	0.00	854.40	854.40	10.10	0.00	1339.5	110.91	2087.55	1931.59	1697.99
	4	3 + Variable Speed Compressor	0.00	992.76	992.76	11.22	0.00	1205.5	99.82	2102.55	1962.19	1751.96
	5	4 + Increase Evap/Cond Coil Area	0.00	1150.87	1150.87	11.84	0.00	1142.9	94.63	2203.03	2069.96	1870.65
	6	5 + Brushless D.C. Fan Motor	0.00	1249.57	1249.57	12.25	0.00	1104.2	91.43	2266.10	2137.54	1944.98
5	7	2 + Increase Comp EER to 12.0	0.00	874.36	874.36	10.75	0.00	1258.8	104.23	2033.21	1886.65	1667.13
	8	7 + Condenser Grooved Tubes	0.00	888.47	888.47	10.90	0.00	1241.4	102.79	2031.31	1886.77	1670.28
6	9	8 + Variable Speed Compressor	0.00	1023.99	1023.99	12.11	0.00	1117.2	92.50	2052.49	1922.41	1727.58
	10	9 + Increase Evap/Cond Coil Area	0.00	1194.87	1194.87	12.78	0.00	1058.5	87.64	2169.33	2046.09	1861.50
7	11	10 + Brushless D.C. Fan Motor	0.00	1301.26	1301.26	13.22	0.00	1023.6	84.75	2243.59	2124.42	1945.91

Notes: This class represents 1.49% of the room air conditioners sold in 1989; average lifetime for all room air conditioners is 15 years; all costs are in 1990 dollars; electricity rate is 8.28 cent/kWh (1996); installation costs and maintenance costs are not included in the above calculations.

Figure 4.12 Life-Cycle Cost for a Room A/C with Reversing Valve (without side louvers)

Table 4.12 Life-Cycle Costs of Room A/C with Reversing Valve (without side louvers)

Standard Level	Design No.	Design Option	Install & Maint	Retail Price	Equipment Price	EER	Annual Energy Use		Annual Energy Cost	Life-Cycle Costs		
							Gas (MMBtu)	Elec (kWh)		4%	6%	10%
1	0	Baseline	0.00	676.10	676.10	8.78	0.00	1040.1	86.12	1633.62	1512.52	1331.14
	1	0 + Add Subcooler	0.00	679.48	679.48	9.10	0.00	1004.3	83.16	1604.04	1487.11	1311.97
2	2	1 + Increase Comp EER to 10.7	0.00	690.54	690.54	9.42	0.00	969.6	80.28	1583.16	1470.27	1301.18
3,4	3	2 + Evap/Cond Grooved Tubes	0.00	701.99	701.99	9.71	0.00	940.8	77.90	1568.09	1458.56	1294.49
	4	3 + Increase Evap/Cond Coil Area	0.00	749.84	749.84	10.50	0.00	870.3	72.06	1551.04	1449.71	1297.94
	5	4 + Variable Speed Compressor	0.00	897.96	897.96	11.66	0.00	783.3	64.86	1619.07	1527.87	1391.27
	6	5 + Brushless D.C. Fan Motor	0.00	1035.11	1035.11	11.75	0.00	777.2	64.35	1750.60	1660.11	1524.58
5	7	3 + Increase Comp EER to 12.0	0.00	746.80	746.80	10.39	0.00	879.6	72.83	1556.56	1454.15	1300.76
6	8	7 + Increase Evap/Cond Coil Area	0.00	823.40	823.40	11.24	0.00	812.8	67.30	1571.67	1477.03	1335.29
	9	8 + Variable Speed Compressor	0.00	932.39	932.39	12.49	0.00	731.5	60.57	1605.81	1520.64	1393.08
7	10	9 + Brushless D.C. Fan Motor	0.00	1088.33	1088.33	12.66	0.00	721.4	59.73	1752.45	1668.46	1542.66

Notes: This class represents 0.50% of the room air conditioners sold in 1989; average lifetime for all room air conditioners is 15 years; all costs are in 1990 dollars; electricity rate is 8.28 cent/kWh (1996); installation costs and maintenance costs are not included in the above calculations.

4.2 PAYBACK PERIODS BY STANDARD 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:

$$\Delta PC + \sum_{t=1}^{PAY} \Delta OC_t = 0 \quad (4)$$

for *PAY*. In general, *PAY* is found by interpolating between the two years when the expression in Eq. 4 changes sign. If the operating cost is constant, the equation has the simple solution:

$$PAY = -\frac{\Delta PC}{\Delta OC} \quad (5)$$

Numerically, the PBP is the ratio of the increase in purchase (and installation) price from the base to the standards 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.

4.2.1 PBP Data Inputs

The data inputs are the same as in Section 4.1.1, except that, in addition, a distribution of design options is projected (by LBL-REM) in the base case. Only those designs that are eliminated by the standard level are included in the calculation of impacts. Consumers whose base case choice is eliminated by standards are assumed to purchase the design option corresponding to the minimum compliance with the standard.

4.2.2 PBP Results

The PBPs by standard level shown in Tables 4.13 through 4.24 are the weighted averages. They compare that portion of the projected distribution of designs in the base case which are less efficient than the standard level to the design at the standard level. Designs with energy consumption at or below the standard level are not affected by the standard, so these are excluded from the calculation of impacts.

Table 4.13 shows the calculation of LCC differences, payback, and CCE. The table is composed of several parts. Table 4.13.a summarizes the equipment cost, operating cost, LCC, and energy use for each design option. Table 4.13.b shows the distribution of units sold in 1996, according to the base case forecast. In the other columns, part of this distribution is expressed as the percent of eliminated units due to standards. That is, if 78% of units sold in the base case correspond to design 0, and standard level 1 (equivalent to design 1) eliminates only design 0, then the fraction of eliminated units due to standard level 1 is 100% for design 0.

Table 4.13.c applies the weights in Table 4.13.b to the values in Table 4.13.a to obtain the weighted average values shown. Table 4.13.d shows the resulting LCC differences, PBPs, and CCE.

4.3 CHANGE IN LIFE-CYCLE COSTS DUE TO STANDARDS

The impact of standards is calculated as the difference in LCC, base case minus standards case. If the LCC difference is greater than zero (positive savings), the standard 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 standard causes a net increase in expenses to the consumer.

4.3.1 Data Inputs for Change in LCC

The data inputs are the same as in Section 4.1.1, except that, in addition, a distribution of design options is projected (by LBL-REM) in the base case. Only those designs that are eliminated by the standard level are included in the calculation of impacts. Consumers whose base case choice is eliminated by standards are assumed to purchase the design option corresponding to the minimum compliance with the standard.

4.3.2 Results for Change in LCC

Tables 4.13 through 4.24 show the LCC differences by standard 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 standard level to the design at the standard level. Designs with energy consumption at or below the standard level are not affected by the standard, so these are excluded from the calculation of impacts. These LCCs are calculated at a 6% discount rate; a higher discount rate (e.g., 10%) gives a smaller difference.

Tables 4.13.d to 4.24.d show lower LCC (positive LCC difference) for virtually all standard levels for all classes. The only case that demonstrates a higher LCC (negative LCC difference) is standard level 7 for all classes except those classes with capacity exceeding 14 kBtu.

4.4 COST OF CONSERVED ENERGY (CCE) DUE TO STANDARDS

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:

$$CCE = -\frac{CRF \cdot \Delta PC}{\Delta E}, \quad (6)$$

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.

4.4.1 CCE Data Inputs

The data inputs are the same as in Section 4.1.1, except that, in addition, a distribution of design options is projected (by LBL-REM) in the base case. Only those designs that are eliminated by the standard level are included in the calculation of impacts. Consumers whose base case choice is eliminated by standards are assumed to purchase the design option corresponding to the minimum compliance with the standard.

4.4.2 CCE Results

Tables 4.13 through 4.24 show the CCE energy site of the standards levels as compared to the base case. Note that the current (1990) and projected (1996) average residential electricity prices are 8.11 and 8.29 cents per kWh, respectively (21). These are equivalent to 23.74 and 24.28 dollars per million Btu, respectively, where one kWh is taken as 3,412 Btu site energy.

Standard levels with CCEs less than projected costs of energy supply include:

All classes: Standard levels 1 through 6.

14 to 20 kBtu with side louvers: Standard level 7.

14 to 20 kBtu without side louvers: Standard level 7.

Over 20 kBtu with side louvers: Standard level 7.

Over 20 kBtu without side louvers: Standard level 7.

Standard levels with CCEs greater than projected costs of energy supply include:

All classes except those with capacity exceeding 14 kBtu: Standard level 7.

Table 4.13.a Cost and Energy Use Summary Room A/C up to 6 kBtu with Louvres

Design Number	Equipment Price	Operating Cost	LCC	Annual Energy Use	
	(1990 \$)	(1990 \$)	(1990 \$)	(kWh)	(MMBtu)
0	287.91	44.06	715.81	532	1.82
1	288.89	41.52	692.18	501	1.71
2	292.68	38.94	670.88	470	1.60
3	296.23	36.90	654.65	446	1.52
4	301.55	34.93	640.75	422	1.44
5	303.34	34.33	636.75	415	1.41
6	330.33	33.00	650.79	399	1.36
9	320.46	32.90	639.96	397	1.36
10	342.52	31.65	649.96	382	1.30
11	430.15	28.48	706.79	344	1.17
12	507.95	27.96	779.52	338	1.15

Table 4.13.b Distribution of Units Sold Below Standards Room A/C up to 6 kBtu with Louvres

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
0	46.23%	74.30%	74.30%	48.04%	46.23%	46.23%	46.23%	46.23%
1	15.99%	25.70%	25.70%	16.62%	15.99%	15.99%	15.99%	15.99%
2	31.00%	<Standard>	<Standard>	32.21%	31.00%	31.00%	31.00%	31.00%
3	3.01%			3.13%	3.01%	3.01%	3.01%	3.01%
4	3.77%			<Standard>	3.77%	3.77%	3.77%	3.77%
5	0.00%				<Standard>	0.00%	0.00%	0.00%
6	0.00%					0.00%	0.00%	0.00%
9	0.00%					0.00%	0.00%	0.00%
10	0.00%					<Standard>	0.00%	0.00%
11	0.00%						<Standard>	0.00%
12	0.00%							<Standard>

Table 4.13.c Weighted Averages of Units Sold Below Standards Room A/C up to 6 kBtu with Louvres

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
Equip. Price (1990 \$)	288.16	288.16	289.87	290.31	290.31	290.31	290.31
Operating Cost (1990 \$)	43.41	43.41	41.76	41.51	41.51	41.51	41.51
Life-Cycle Cost (1990 \$)	709.74	709.74	695.50	693.43	693.43	693.43	693.43
Energy Use (MMBtu/yr)	1.79	1.79	1.72	1.71	1.71	1.71	1.71

Table 4.13.d Life-Cycle Cost Differences (\$1990), Payback Periods (year) and Costs of Conserved Energy (at 6% real) Room A/C up to 6 kBtu with Louvres

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
LCC difference	38.9	38.9	54.7	56.7	53.5	43.5	-86.1
Payback	1.0	1.0	1.7	1.8	3.5	5.3	16.1
CCE (cent/kWH)	0.9	0.9	1.5	1.5	3.0	4.5	13.7
CCE (\$/MMBtu)	2.5	2.5	4.3	4.5	8.7	13.2	40.1

Table 4.14.a Cost and Energy Use Summary Room A/C up to 6 kBtu without Louvres

Design Number	Equipment Price (1990 \$)	Operating Cost (1990 \$)	LCC (1990 \$)	Annual Energy Use	
				(kWh)	(MMBtu)
0	287.91	45.71	731.81	552	1.88
1	288.89	42.99	706.42	519	1.77
2	292.68	40.40	685.04	488	1.66
3	296.23	38.25	667.68	462	1.58
4	301.55	36.18	652.89	437	1.49
5	303.34	35.56	648.73	430	1.47
6	330.28	34.19	662.32	413	1.41
9	320.46	34.12	651.86	412	1.41
10	342.48	32.80	661.01	396	1.35
11	430.13	29.52	716.82	357	1.22
12	507.92	28.99	789.46	350	1.19

Table 4.14.b Distribution of Units Sold Below Standards Room A/C up to 6 kBtu without Louvres

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
0	29.06%	39.68%	39.68%	29.06%	29.06%	29.06%	29.06%	29.06%
1	44.17%	60.32%	60.32%	44.17%	44.17%	44.17%	44.17%	44.17%
2	26.63%	<Standard>	<Standard>	26.63%	26.63%	26.63%	26.63%	26.63%
3	0.15%			0.15%	0.15%	0.15%	0.15%	0.15%
4	0.00%			<Standard>	0.00%	0.00%	0.00%	0.00%
5	0.00%				<Standard>	0.00%	0.00%	0.00%
6	0.00%					0.00%	0.00%	0.00%
9	0.00%					<Standard>	0.00%	0.00%
10	0.00%						<Standard>	0.00%
11	0.00%							0.00%
12	0.00%							<Standard>

Table 4.14.c Weighted Averages of Units Sold Below Standards Room A/C up to 6 kBtu without Louvres

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
Equip. Price (1990 \$)	288.50	288.50	289.63	289.63	289.63	289.63	289.63
Operating Cost (1990 \$)	44.07	44.07	43.08	43.08	43.08	43.08	43.08
Life-Cycle Cost (1990 \$)	716.50	716.50	708.05	708.05	708.05	708.05	708.05
Energy Use (MMBtu/yr)	1.82	1.82	1.78	1.78	1.78	1.78	1.78

Table 4.14.d Life-Cycle Cost Differences (\$1990), Payback Periods (year) and Costs of Conserved Energy (at 6% real) Room A/C up to 6 kBtu without Louvres

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
LCC difference	31.5	31.5	55.2	59.3	56.2	47.0	-81.4
Payback	1.1	1.1	1.7	1.8	3.4	5.1	15.5
CCE (cent/kWh)	1.0	1.0	1.5	1.6	2.9	4.4	13.2
CCE (\$/MMBtu)	2.8	2.8	4.3	4.6	8.6	12.8	38.7

Table 4.15.a Cost and Energy Use Summary Room A/C 6 to 8 kBtu with Louvres

Design Number	Equipment Price (1990 \$)	Operating Cost (1990 \$)	LCC (1990 \$)	Annual Energy Use	
				(kWh)	(MMBtu)
0	396.22	55.55	935.74	671	2.29
1	398.05	54.13	923.82	654	2.23
2	403.33	50.39	892.75	609	2.08
3	407.67	48.99	883.50	592	2.02
4	415.53	47.98	881.55	580	1.98
5	450.03	45.85	895.38	554	1.89
8	439.49	45.82	884.52	553	1.89
9	466.36	43.74	891.21	528	1.80
10	573.95	39.37	956.33	475	1.62
11	672.99	38.68	1048.62	467	1.59

Table 4.15.b Distribution of Units Sold Below Standards Room A/C 6 to 8 kBtu with Louvres

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1	22.17%	100.00%	100.00%	25.69%	25.69%	22.82%	22.55%	22.17%
2	51.17%	<Standard>	<Standard>	59.29%	59.29%	52.68%	52.05%	51.17%
3	12.96%			15.02%	15.02%	13.34%	13.18%	12.96%
4	7.39%			<Standard>	<Standard>	7.61%	7.52%	7.39%
5	3.45%					3.55%	3.51%	3.45%
8	1.16%					<Standard>	1.18%	1.16%
9	1.10%						<Standard>	1.10%
10	0.60%							0.60%
11	0.00%							<Standard>

Table 4.15.c Weighted Averages of Units Sold below Standards Room A/C 6 to 8 kBtu with Louvres

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
Equip. Price (1990 \$)	398.05	398.05	402.63	402.63	405.29	405.69	407.37
Operating Cost (1990 \$)	54.13	54.13	51.14	51.14	50.71	50.65	50.51
Life-Cycle Cost (1990 \$)	923.82	923.82	899.34	899.34	897.85	897.69	897.97
Energy Use (MMBtu/yr)	2.23	2.23	2.11	2.11	2.09	2.09	2.08

Table 4.15.d Life-Cycle Cost Differences (\$1990), Payback Periods (year) and Costs of Conserved Energy(at 6% real) Room A/C 6 to 8 kBtu with Louvres

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
LCC difference	31.1	31.1	17.8	17.8	13.3	6.5	-150.6
Payback	1.4	1.4	4.1	4.1	7.0	8.8	22.5
CCE (cent/kWH)	1.2	1.2	3.5	3.5	6.0	7.5	19.1
CCE (\$/MMBtu)	3.5	3.5	10.2	10.2	17.5	21.9	56.1

Table 4.16.a Cost and Energy Use Summary Room A/C 6 to 8 kBtu without Louvres

Design Number	Equipment Price (1990 \$)	Operating Cost (1990 \$)	LCC (1990 \$)	Annual Energy Use	
				(kWh)	(MMBtu)
0	396.22	57.55	955.12	695	2.37
1	398.05	56.07	942.64	677	2.31
2	403.33	52.45	912.69	633	2.16
3	407.67	50.86	901.67	614	2.10
4	415.53	49.74	898.60	601	2.05
5	449.92	47.57	911.92	575	1.96
8	439.49	47.49	900.76	574	1.96
9	466.28	45.35	906.73	548	1.87
10	573.90	40.81	970.28	493	1.68
11	672.92	40.15	1062.86	485	1.65

Table 4.16.b Distribution of Units Sold Below Standards Room A/C 6 to 8 kBtu without Louvres

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
0	0.00%	<Standard>	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1	0.00%		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2	57.25%		100.00%	81.79%	81.79%	57.25%	57.25%	57.25%
3	12.75%		<Standard>	18.21%	18.21%	12.75%	12.75%	12.75%
4	7.54%			<Standard>	<Standard>	7.54%	7.54%	7.54%
5	22.46%					22.46%	22.46%	22.46%
8	0.00%					<Standard>	0.00%	0.00%
9	0.00%						<Standard>	0.00%
10	0.00%							0.00%
11	0.00%							<Standard>

Table 4.16.c Weighted Averages of Units Sold Below Standards Room A/C 6 to 8 kBtu without Louvres

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
Equip. Price (1990 \$)	NA	403.33	404.12	404.12	415.27	415.27	415.27
Operating Cost (1990 \$)	NA	52.45	52.16	52.16	50.95	50.95	50.95
Life-Cycle Cost (1990 \$)	NA	912.69	910.68	910.68	910.05	910.05	910.05
Energy Use (MMBtu/yr)	NA	2.16	2.15	2.15	2.10	2.10	2.10

Table 4.16.d Life-Cycle Cost Differences (\$1990), Payback Periods (year) and Costs of Conserved Energy (at 6% real) Room A/C 6 to 8 kBtu, without Louvres

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
LCC difference	NA	11.0	12.1	12.1	9.3	3.3	-152.8
Payback	NA	2.7	4.7	4.7	7.0	9.1	23.9
CCE (cent/kWh)	NA	2.3	4.0	4.0	6.0	7.8	20.3
CCE (\$/MMBtu)	NA	6.9	11.8	11.8	17.5	22.8	59.6

Table 4.17.a Cost and Energy Use Summary Room A/C 8 to 14 kBtu with Louvres

Design Number	Equipment Price (1990 \$)	Operating Cost (1990 \$)	LCC (1990 \$)	Annual Energy Use	
				(kWh)	(MMBtu)
0	504.00	80.81	1248.87	976	3.33
1	506.52	77.67	1260.92	938	3.20
2	514.77	75.05	1243.67	906	3.09
3	523.30	72.93	1231.62	881	3.01
4	559.40	67.41	1214.08	814	2.78
7	556.71	68.41	1221.12	826	2.82
8	616.11	62.97	1227.69	760	2.59
9	695.34	56.68	1245.80	684	2.34
10	811.93	55.85	1354.35	675	2.30

Table 4.17.b Distribution of Units Sold Below Standards Room A/C 8 to 14 kBtu with Louvres

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
0	46.09%	<Standard>	58.86%	49.49%	49.49%	48.54%	47.62%	46.09%
1	32.22%		41.14%	34.60%	34.60%	33.93%	33.29%	32.22%
2	14.82%		<Standard>	15.91%	15.91%	15.61%	15.31%	14.82%
3	1.58%			<Standard>	<Standard>	1.66%	1.63%	1.58%
4	0.24%					0.25%	0.25%	0.24%
7	1.83%					<Standard>	1.89%	1.83%
8	2.23%						<Standard>	2.23%
9	0.98%							0.98%
10	0.00%							<Standard>

Table 4.17.c Weighted Averages of Units Sold Below Standards Room A/C 8 to 14 kBtu with Louvres

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
Equip. Price (1990 \$)	NA	505.04	506.59	506.59	507.00	507.94	512.19
Operating Cost (1990 \$)	NA	79.52	78.81	78.81	78.68	78.49	77.93
Life-Cycle Cost (1990 \$)	NA	1277.37	1272.01	1272.01	1271.19	1270.24	1269.05
Energy Use (MMBtu/yr)	NA	3.28	3.25	3.25	3.24	3.23	3.21

Table 4.17.d Life-Cycle Cost Differences (\$1990), Payback Periods (year) and Costs of Conserved Energy (at 6% real) Room A/C 8 to 14 kBtu with Louvres

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
LCC difference	NA	33.7	40.4	40.4	50.1	42.6	-85.3
Payback	NA	2.2	2.8	2.8	4.8	7.0	13.6
CCE (cent/kWh)	NA	1.9	2.4	2.4	4.1	5.9	11.6
CCE (\$/MMBtu)	NA	5.4	7.1	7.1	12.1	17.4	33.9

Table 4.18.a Cost and Energy Use Summary Room A/C 8 to 14 kBtu without Louvres

Design Number	Equipment Price (1990 \$)	Operating Cost (1990 \$)	LCC (1990 \$)	Annual Energy Use	
				(kWh)	(MMBtu)
0	504.00	84.10	1320.80	1016	3.47
1	506.52	80.20	1285.44	969	3.30
2	514.77	78.10	1273.27	943	3.22
3	523.30	76.02	1261.61	918	3.13
4	559.19	70.22	1241.21	848	2.89
7	556.71	71.08	1247.09	858	2.93
8	614.74	65.59	1251.73	792	2.70
9	695.17	59.03	1268.47	713	2.43
10	811.55	58.19	1376.72	703	2.40

Table 4.18.b Distribution of Units Sold Below Standards Room A/C 8 to 14 kBtu without Louvres

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
0	26.28%	<Standard>	33.99%	33.45%	33.45%	26.30%	26.28%	26.28%
1	51.04%		66.01%	64.96%	64.96%	51.09%	51.04%	51.04%
2	1.25%		<Standard>	1.59%	1.59%	1.25%	1.25%	1.25%
3	21.34%			<Standard>	<Standard>	21.36%	21.34%	21.34%
4	0.00%					0.00%	0.00%	0.00%
7	0.09%					<Standard>	0.09%	0.09%
8	0.00%						<Standard>	0.00%
9	0.00%							0.00%
10	0.00%							<Standard>

Table 4.18.c Weighted Averages of Units Sold Below Standards Room A/C 8 to 14 kBtu without Louvres

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
Equip. Price (1990 \$)	NA	505.66	505.81	505.81	509.54	509.59	509.59
Operating Cost (1990 \$)	NA	81.53	81.47	81.47	80.31	80.30	80.30
Life-Cycle Cost (1990 \$)	NA	1297.46	1297.07	1297.07	1289.50	1289.46	1289.46
Energy Use (MMBtu/yr)	NA	3.36	3.36	3.36	3.31	3.31	3.31

Table 4.18.d Life-Cycle Cost Differences (\$1990), Payback Periods (year) and Costs of Conserved Energy (at 6% real) Room A/C 8 to 14 kBtu without Louvres

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
LCC difference	NA	24.2	35.5	35.5	42.4	37.7	-87.3
Payback	NA	2.7	3.2	3.2	5.1	7.1	13.7
CCE (cent/kWH)	NA	2.3	2.7	2.7	4.4	6.1	11.6
CCE (\$/MMBtu)	NA	6.6	8.0	8.0	12.8	17.9	34.1

Table 4.19.a Cost and Energy Use Summary Room A/C 14 to 20 kBtu with Louvres

Design Number	Equipment Price	Operating Cost	LCC	Annual Energy Use	
	(1990 \$)	(1990 \$)	(1990 \$)	(kWh)	(MMBtu)
0	627.98	124.86	1840.67	1508	5.15
1	635.69	119.76	1798.85	1446	4.94
2	653.19	111.34	1734.56	1345	4.59
3	669.21	108.36	1721.63	1309	4.47
4	777.58	97.53	1724.82	1178	4.02
7	684.85	101.76	1673.18	1229	4.19
8	695.90	100.92	1676.11	1219	4.16
9	847.01	90.83	1729.19	1097	3.74
10	936.77	85.61	1768.21	1034	3.53
11	988.64	82.71	1791.93	999	3.41

Table 4.19.b Distribution of Units Sold Below Standards Room A/C 14 to 20 kBtu with Louvres

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
0	34.41%	<Standard>	40.52%	40.52%	36.74%	34.41%	34.41%	34.41%
1	50.52%		59.48%	59.48%	53.94%	50.52%	50.52%	50.52%
2	8.73%		<Standard>	<Standard>	9.32%	8.73%	8.73%	8.73%
3	5.25%				<Standard>	5.25%	5.25%	5.25%
4	0.00%					0.00%	0.00%	0.00%
7	1.09%					1.09%	1.09%	1.09%
8	0.00%					<Standard>	<Standard>	0.00%
9	0.00%							0.00%
10	0.00%							0.00%
11	0.00%							<Standard>

Table 4.19.c Weighted Averages of Units Sold Below Standards Room A/C 14 to 20 kBtu with Louvres

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
Equip. Price (1990 \$)	NA	632.57	632.57	634.49	636.86	636.86	636.86
Operating Cost (1990 \$)	NA	121.83	121.83	120.85	119.99	119.99	119.99
Life-Cycle Cost (1990 \$)	NA	1815.79	1815.79	1808.22	1802.20	1802.20	1802.20
Energy Use (MMBtu/yr)	NA	5.02	5.02	4.98	4.94	4.94	4.94

Table 4.19.d Life-Cycle Cost Differences (\$1990), Payback Periods (year) and Costs of Conserved Energy (at 6% real) Room A/C 14 to 20 kBtu with Louvres

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
LCC difference	NA	81.2	81.2	86.6	126.1	126.1	10.3
Payback	NA	2.0	2.0	2.8	3.1	3.1	9.4
CCE (cent/kWH)	NA	1.7	1.7	2.4	2.6	2.6	8.0
CCE (\$/MMBtu)	NA	4.9	4.9	6.9	7.7	7.7	23.6

Table 4.20.a Cost and Energy Use Summary Room A/C 14 to 20 kBtu without Louvres

Design Number	Equipment Price (1990 \$)	Operating Cost (1990 \$)	LCC (1990 \$)	Annual Energy Use	
				(kWh)	(MMBtu)
0	627.98	129.66	1887.24	1566	5.34
1	635.69	123.65	1836.64	1493	5.10
2	653.19	114.90	1769.14	1388	4.73
3	669.21	111.90	1756.05	1351	4.61
4	777.58	100.72	1755.78	1216	4.15
7	684.85	104.68	1701.57	1264	4.31
8	695.90	103.62	1702.32	1251	4.27
9	847.01	93.26	1752.75	1126	3.84
10	935.77	88.37	1794.07	1067	3.64
11	988.50	85.49	1818.81	1033	3.52

Table 4.20.b Distribution of Units Sold Below Standards Room A/C 14 to 20 kBtu without Louvres

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
0	26.32%	<Standard>	31.33%	31.33%	26.32%	26.32%	26.32%	26.32%
1	57.68%		68.67%	68.67%	57.68%	57.68%	57.68%	57.68%
2	16.00%		<Standard>	<Standard>	16.00%	16.00%	16.00%	16.00%
3	0.00%				<Standard>	0.00%	0.00%	0.00%
4	0.00%					0.00%	0.00%	0.00%
7	0.00%					0.00%	0.00%	0.00%
8	0.00%					<Standard>	<Standard>	0.00%
9	0.00%							0.00%
10	0.00%							0.00%
11	0.00%							<Standard>

Table 4.20.c Weighted Averages of Units Sold Below Standards Room A/C 14 to 20 kBtu without Louvres

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
Equip. Price (1990 \$)	NA	633.27	633.27	636.46	636.46	636.46	636.46
Operating Cost (1990 \$)	NA	125.53	125.53	123.83	123.83	123.83	123.83
Life-Cycle Cost (1990 \$)	NA	1852.49	1852.49	1839.16	1839.16	1839.16	1839.16
Energy Use (MMBtu/yr)	NA	5.17	5.17	5.10	5.10	5.10	5.10

Table 4.20.d Life-Cycle Cost Differences (\$1990), Payback Periods (year) and Costs of Conserved Energy (at 6% real) Room A/C 14 to 20 kBtu without Louvres

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
LCC difference	NA	83.4	83.4	83.1	136.8	136.8	20.3
Payback	NA	1.9	1.9	2.7	2.9	2.9	9.2
CCE (cent/kWh)	NA	1.6	1.6	2.3	2.5	2.5	7.8
CCE (\$/MMBtu)	NA	4.7	4.7	6.9	7.3	7.3	22.9

Table 4.21.a Cost and Energy Use Summary Room A/C over 20 kBtu with Louvres

Design Number	Equipment Price (1990 \$)	Operating Cost (1990 \$)	LCC (1990 \$)	Annual Energy Use	
				(kWh)	(MMBtu)
0	864.79	183.39	2645.88	2215	7.56
1	873.76	176.45	2587.46	2131	7.27
2	885.53	172.32	2559.18	2081	7.10
3	898.51	167.92	2529.38	2028	6.92
4	1031.65	151.13	2499.43	1825	6.23
7	928.38	158.33	2466.12	1912	6.52
8	1046.22	142.50	2430.20	1721	5.87
9	1159.16	135.81	2478.17	1640	5.60
10	1252.32	133.37	2547.60	1611	5.50

Table 4.21.b Distribution of Units Sold Below Standards Room A/C over 20 kBtu with Louvres

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
0	53.26%	<Standard>	<Standard>	<Standard>	75.27%	57.15%	53.26%	53.26%
1	13.43%				18.98%	14.41%	13.43%	13.43%
2	4.07%				5.75%	4.37%	4.07%	4.07%
3	22.43%				<Standard>	24.07%	22.43%	22.43%
4	0.00%					0.00%	0.00%	0.00%
7	6.81%					<Standard>	6.81%	6.81%
8	0.00%						<Standard>	0.00%
9	0.00%							0.00%
10	0.00%							<Standard>

Table 4.21.c Weighted Averages of Units Sold Below Standards Room A/C over 20 kBtu with Louvres

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
Equip. Price (1990 \$)	NA	NA	NA	867.69	875.10	878.73	878.73
Operating Cost (1990 \$)	NA	NA	NA	181.44	178.18	176.83	176.83
Life-Cycle Cost (1990 \$)	NA	NA	NA	2629.81	2605.63	2596.13	2596.13
Energy Use (MMBtu/yr)	NA	NA	NA	7.48	7.34	7.29	7.29

Table 4.21.d Life-Cycle Cost Differences (\$1990), Payback Periods (year) and Costs of Conserved Energy (at 6% real) Room A/C over 20 kBtu with Louvres

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
LCC difference	NA	NA	NA	100.4	139.5	165.9	48.5
Payback	NA	NA	NA	2.3	2.7	4.9	8.6
CCE (cent/kWH)	NA	NA	NA	1.9	2.3	4.2	7.3
CCE (\$/MMBtu)	NA	NA	NA	5.7	6.7	12.2	21.5

Table 4.22.a Cost and Energy Use Summary Room A/C over 20 kBtu without Louvres

Design Number	Equipment Price	Operating Cost	LCC	Annual Energy Use	
	(1990 \$)	(1990 \$)	(1990 \$)	(kWh)	(MMBtu)
0	845.25	189.90	2689.62	2293	7.83
1	854.02	182.65	2627.95	2206	7.53
2	865.51	178.33	2597.46	2154	7.35
3	878.20	173.76	2565.76	2099	7.16
4	1008.34	156.38	2527.10	1889	6.44
7	907.40	163.80	2498.30	1978	6.75
8	1022.58	147.42	2454.33	1780	6.07
9	1132.41	140.73	2499.18	1700	5.80
10	1223.89	138.28	2566.86	1670	5.70

Table 4.22.b Distribution of Units Sold Below Standards Room A/C over 20 kBtu without Louvres

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
0	31.91%	<Standard>	<Standard>	<Standard>	40.61%	32.36%	31.91%	31.91%
1	45.27%				57.62%	45.91%	45.27%	45.27%
2	1.39%				1.77%	1.41%	1.39%	1.39%
3	20.04%				<Standard>	20.32%	20.04%	20.04%
4	0.00%					0.00%	0.00%	0.00%
7	1.38%					<Standard>	1.38%	1.38%
8	0.00%						<Standard>	0.00%
9	0.00%							0.00%
10	0.00%							<Standard>

Table 4.22.c Weighted Averages of Units Sold Below Standards Room A/C over 20 kBtu without Louvres

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
Equip. Price (1990 \$)	NA	NA	NA	850.66	856.26	856.96	856.96
Operating Cost (1990 \$)	NA	NA	NA	185.52	183.13	182.86	182.86
Life-Cycle Cost (1990 \$)	NA	NA	NA	2652.46	2634.84	2632.95	2632.95
Energy Use (MMBtu/yr)	NA	NA	NA	7.64	7.55	7.54	7.54

Table 4.22.d Life-Cycle Cost Differences (\$1990), Payback Periods (year) and Costs of Conserved Energy (at 6% real) Room A/C over 20 kBtu without Louvres

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
LCC difference	NA	NA	NA	86.7	136.5	178.6	66.1
Payback	NA	NA	NA	2.3	2.6	4.7	8.2
CCE (cent/kWH)	NA	NA	NA	2.0	2.3	4.0	7.0
CCE (\$/MMBtu)	NA	NA	NA	5.9	6.6	11.7	20.6

Table 4.23.a Cost and Energy Use Summary Heat Pump Room A/C with Reversing Valve

Design Number	Equipment Price	Operating Cost	LCC	Annual Energy Use	
	(1990 \$)	(1990 \$)	(1990 \$)	(kWh)	(MMBtu)
0	801.76	128.56	2050.40	1553	5.30
1	811.61	122.31	1999.54	1477	5.04
2	833.94	113.97	1940.81	1376	4.70
3	854.40	110.91	1931.59	1340	4.57
4	992.76	99.82	1962.19	1206	4.11
7	874.36	104.23	1886.65	1259	4.30
8	888.47	102.79	1886.77	1241	4.24
9	1023.99	92.50	1922.41	1117	3.81
10	1194.87	87.64	2046.09	1058	3.61
11	1301.26	84.75	2124.42	1024	3.49

Table 4.23.b Distribution of Units Sold Below Standards Heat Pump Room A/C with Reversing Valve

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
0	31.76%	<Standard>	38.95%	38.95%	32.88%	32.18%	31.76%	31.76%
1	49.78%		61.05%	61.05%	51.54%	50.44%	49.78%	49.78%
2	15.05%		<Standard>	<Standard>	15.58%	15.25%	15.05%	15.05%
3	2.11%				<Standard>	2.14%	2.11%	2.11%
4	0.00%					0.00%	0.00%	0.00%
7	1.30%					<Standard>	1.30%	1.30%
8	0.00%						0.00%	0.00%
9	0.00%						<Standard>	0.00%
10	0.00%							0.00%
11	0.00%							<Standard>

Table 4.23.c Weighted Averages of Units Sold Below Standards Heat Pump Room A/C with Reversing Valve

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
Equip. Price (1990 \$)	NA	807.77	807.77	811.85	812.76	813.56	813.56
Operating Cost (1990 \$)	NA	124.74	124.74	123.07	122.81	122.56	122.56
Life-Cycle Cost (1990 \$)	NA	2019.35	2019.35	2007.11	2005.50	2003.95	2003.95
Energy Use (MMBtu/yr)	NA	5.14	5.14	5.07	5.06	5.05	5.05

Table 4.23.d Life-Cycle Cost Differences (\$1990), Payback Periods (year) and Costs of Conserved Energy (at 6% real) Heat Pump Room A/C with Reversing Valve

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
LCC difference	NA	78.5	78.5	75.5	118.8	81.5	-120.5
Payback	NA	2.4	2.4	3.5	3.3	7.0	12.9
CCE (cent/kWH)	NA	2.1	2.1	3.0	2.8	6.0	11.0
CCE (\$/MMBtu)	NA	6.1	6.1	8.7	8.3	17.5	32.2

Table 4.24.a Cost and Energy Use Summary Heat Pump Room A/C with Reversing Valve

Design Number	Equipment Price (1990 \$)	Operating Cost (1990 \$)	LCC (1990 \$)	Annual Energy Use (kWh)	Annual Energy Use (MMBtu)
0	676.10	86.12	1512.52	1040	3.55
1	679.48	83.16	1487.11	1004	3.43
2	690.54	80.28	1470.27	970	3.31
3	701.99	77.90	1458.56	941	3.21
4	749.84	72.06	1449.71	870	2.97
7	746.80	72.83	1454.15	880	3.00
8	823.40	67.30	1477.03	813	2.77
9	932.39	60.57	1520.64	732	2.50
10	1088.33	59.73	1668.46	721	2.46

Table 4.24.b Distribution of Units Sold Below Standards Heat Pump Room A/C with Reversing Valve

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
0	30.18%	<Standard>	38.17%	33.21%	33.21%	30.18%	30.18%	30.18%
1	48.89%		61.83%	53.80%	53.80%	48.89%	48.89%	48.89%
2	11.80%		<Standard>	12.99%	12.99%	11.80%	11.80%	11.80%
3	9.13%			<Standard>	<Standard>	9.13%	9.13%	9.13%
4	0.00%					0.00%	0.00%	0.00%
7	0.00%					<Standard>	0.00%	0.00%
8	0.00%						<Standard>	0.00%
9	0.00%							0.00%
10	0.00%							<Standard>

Table 4.24.c Weighted Averages of Units Sold Below Standards Heat Pump Room A/C with Reversing Valve

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
Equip. Price (1990 \$)	NA	678.19	679.79	679.79	681.82	681.82	681.82
Operating Cost (1990 \$)	NA	84.29	83.77	83.77	83.23	83.23	83.23
Life-Cycle Cost (1990 \$)	NA	1496.81	1493.36	1493.36	1490.19	1490.19	1490.19
Energy Use (MMBtu/yr)	NA	3.47	3.45	3.45	3.43	3.43	3.43

Table 4.24.d Life-Cycle Cost Differences (\$1990), Payback Periods (year) and Costs of Conserved Energy(at 6% real) Heat Pump Room A/C with Reversing Valve

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5	Trial Standard Level 6	Trial Standard Level 7
LCC difference	NA	26.5	34.8	34.8	36.0	13.2	-178.3
Payback	NA	3.1	3.8	3.8	6.2	8.9	17.3
CCE (cent/kWH)	NA	2.6	3.2	3.2	5.3	7.6	14.7
CCE (\$/MMBtu)	NA	7.7	9.4	9.4	15.6	22.2	43.2

4.5 LCC SENSITIVITY ANALYSIS

The sensitivity of the national LCC results were tested by varying assumptions about energy prices and equipment prices. These tables 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. Projected (1992) state energy prices (22) relative to the national average were applied to the projected 1996 national average price from the *Annual Energy Outlook 1991* to obtain state prices for 1996. (This represents a wider range of prices than analyzed in previous analyses, which used 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;

Figure 4.13 and Table 4.25 summarize the results of the sensitivity analysis. These include:

- graph of highest and lowest LCC sensitivity, and reference case;
- table of LCCs for all sensitivity cases. The table also shows the number of sensitivity cases for which each design option is the minimum LCC.

Figure 4.13 Life-Cycle Cost for a Room A/C < 6K Btuh (with side louvers)

Table 4.25 Sensitivity Summary of Life-Cycle Costs of Room Air Conditioners < 6K Btuh (with Side Louvers)

Standard Level											7 Std Level @	Design Option
Design Option	0	1	2	3	4	5	9	10	11	12	min LCC	@ min LCC
Reference	716	692	671	655	641	637	640	650	707	780	4	5
1	523	510	500	493	488	486	496	511	582	657	4	5
2	730	707	686	670	656	652	661	674	753	845	4	5
3	537	525	515	508	503	502	517	535	628	722	4	5
4	918	883	850	824	801	794	791	795	837	908	5	9
5	701	678	656	640	625	621	619	626	661	714	5	9
6	904	868	835	809	785	779	770	771	791	842	5	9
# of cases as min LCC						4	3					

CHAPTER 5. IMPACTS ON THE MANUFACTURERS OF ROOM AIR CONDITIONERS

5.1 LONG-RUN IMPACTS

The analysis shows that compared to the 1996 base case, at all trial standards levels except level 5, the room air conditioner industry is likely to experience a return on equity (ROE) decrease. At standards level 1, there is approximately a 61% chance that ROE will decrease, with an expected decrease of 0.04%. At standards level 2, there is approximately a 99% chance of a decrease in ROE with an expected decrease of 0.06%. At standards level 3, there is approximately a 60% chance of an decrease in ROE with an expected decrease of 0.12%. At standards level 4, there is approximately a 58% chance of an decrease in ROE with an expected decrease of 0.11%. At standards level 5, there is approximately a 52% chance of an increase in ROE with an expected increase of 0.06%. At standards level 6, there is approximately a 66% chance of a decrease in ROE with an expected decrease of 0.4%. At level 7, there is an estimated 57% chance of a decrease in ROE with an expected decrease of 0.17%. These results are based on 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.

5.1.1 Qualitative analysis

According to reports from within the industry, room air conditioner manufacturing is characterized by economies of scale; this means that for the purposes of price determination there are fixed costs. Depending on the standards level considered, these 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 standards are imposed, and to the extent that standards induce an increase in variable costs, such costs will be more than completely passed on in the form of a price increase which in itself is profitable, but which also tends to reduce profit because of the effect of a price increase on sales. If standards induce 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 room air conditioners more attractive and thereby increasing demand. Since demand is a function of purchase price and operating cost (i.e., life-cycle cost) under constant life-cycle cost elasticity, as price changes, so does price elasticity, and consequently, markup. (For instance, as price rises, price elasticity rises, and markup falls.) The model calculates that when these effects are combined, they are more likely to reduce economic profits than increase them at all standards levels (except level 5).

5.1.2 Quantitative analysis

Table 5.1 summarizes all essential outputs from the LBL-MIM simulations using the primary scenario for room air conditioners. Six other scenarios are summarized and discussed in the sensitivity section, Section 5.4.

Once the above interpretations are understood, the results of the model concerning the long-run impact of standards on the room air conditioner manufacturing industry can be read from the output table.

Table 5.1 Room Air Conditioners: Primary Scenario – Long-Run

	1996 BASE	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
Shipments (in Mil)	1.00	1.00	1.00	1.01	1.01	0.99	0.97	0.82
% change		0.32%	0.42%	0.69%	0.66%	-0.50%	-3.06%	-17.51%
S.E.		1.17%	3.22%	6.29%	7.40%	35.97%	11.05%	16.01%
Price	\$299.75	\$300.25	\$303.39	\$307.28	\$309.36	\$327.09	\$358.16	\$552.68
% change		0.17%	1.22%	2.51%	3.21%	9.12%	19.49%	84.38%
S.E.		0.51%	0.87%	1.47%	1.67%	3.71%	6.03%	26.66%
Revenue (in \$M)	299.70	301.18	304.62	309.36	311.37	325.41	347.14	455.87
% change		0.49%	1.64%	3.22%	3.89%	8.58%	15.83%	52.11%
S.E.		1.16%	3.03%	6.24%	6.98%	38.06%	12.13%	31.10%
Net Income (in \$M)	17.16	17.13	17.13	17.10	17.12	17.26	16.52	16.51
Difference		-0.03	-0.03	-0.06	-0.04	0.10	-0.64	-0.65
S.E.		0.54	1.05	2.34	2.27	30.35	5.09	17.63
ROE	8.56%	8.52%	8.51%	8.45%	8.46%	8.62%	7.87%	7.05%
Difference		-0.04%	-0.06%	-0.12%	-0.11%	0.06%	-0.70%	-1.51%
S.E.		0.17%	0.26%	0.47%	0.54%	1.00%	1.71%	8.74%

5.2 SHORT-RUN IMPACTS

The business cycle presents the room air conditioner manufacturing industry with fairly sharp periodic fluctuations in demand, much larger than the fluctuations predicted for any of the standards levels. These normal demand fluctuations present the same types of opportunities for price competition that will accompany fluctuations resulting from a change in standards. 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 room air conditioners; a 10% demand increase has the reverse effect. This effect is taken into account as described in Volume A, Chapter 3, Section 3.3.4.2, of this Technical Support Document, and is used to produce a short-run version of the output table that is displayed in Table 5.2. Note that at each standards level analyzed for the room air conditioner manufacturing industry, the short-run ROE results are generally lower than the long-run results. For reasons that are explained in the above reference, the short-run change has been overestimated. Thus the values for change in Table 5.2 should be viewed as somewhat too large in absolute value.

Table 5.2 Room Air Conditioner: Primary Scenario – Short-Run

	1990 BASE	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
Shipments (in Mil)	1.00	1.00	1.00	1.01	1.01	0.99	0.97	0.84
% change		0.29%	0.38%	0.63%	0.61%	-0.50%	-2.90%	-15.78%
Price	\$299.75	\$300.57	\$303.76	\$307.78	\$309.85	\$327.04	\$356.75	\$539.28
% change		0.28%	1.34%	2.68%	3.37%	9.11%	19.02%	79.91%
Revenue (in \$M)	299.70	301.40	304.86	309.69	311.69	325.37	346.36	454.12
% change		0.57%	1.72%	3.33%	4.00%	8.56%	15.57%	51.52%
Net Income (in \$M)	17.16	17.16	17.16	17.03	17.04	16.84	10.84	-10.02
Difference		-0.00	0.00	-0.13	-0.13	-0.32	-6.33	-27.18
ROE	8.56%	8.54%	8.53%	8.41%	8.42%	8.42%	5.16%	-4.28%
Difference		-0.03%	-0.04%	-0.15%	-0.15%	-0.15%	-3.41%	-12.84%
S.E.		0.68%	1.03%	1.41%	1.23%	2.72%	2.61%	66.11%

5.3 IMPACT AS A FUNCTION OF FIRM SIZE

As described in the Industry Analysis section (Volume A, Chapter 4), the industry is dominated by several large players with a variety of smaller firms that manufacture both high-end (i.e., higher efficiency) and standard room air conditioners. Typically, in this (and other similar) industry, average cost decreases with increasing firm size. Thus, 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. 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 be, on average, in more danger of failing or being bought out than will the larger firms. Because of the generally greater financial precariousness 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.

Since some small firms have more energy-efficient models and some have models of average efficiency, the impact of higher efficiency standards on small firms is likely to be mixed. However, if standards are technologically difficult to meet, they may hurt selected smaller firms the most because smaller firms have less sophisticated research and development capabilities.

5.4 SENSITIVITY ANALYSIS FOR ROOM AIR CONDITIONERS

The three following subsections discuss different aspects of the sensitivity analysis conducted by LBL-MIM. The first subsection, on sensitivity charts, shows the implications of the uncertainty of each control variable for the prediction of ROE. The next subsection shows six alternative scenarios that are of particular importance and deserve a more detailed analysis than those randomly generated by Monte Carlo runs. The last subsection shows the use of Monte Carlo runs to find combinations of errors that would cause the change in ROE to be considerably more negative than is predicted.

5.4.1 Sensitivity Charts

Table 5.3 lists the sensitivities of ROE to changes in control panel inputs. The variables analyzed are industry price elasticity of demand (IPE), discount rate (RD), the equity cost of capital (ECC), economic profit (EP), the fixed part of costs (FCA), the fixed part of one-time costs (F1X), one-time capital costs (CC.N), one-time variable costs (dVC.N), and the shape parameter of the demand curve (ro.N).

Table 5.3 Room Air Conditioner Sensitivity Chart: Primary Scenario (Sensitivity of ROE to 1. S.E. Change in Control Variable)

Control Variables			Possible Standards Levels						
Name	Value	Changed	1	2	3	4	5	6	7
IPE	-0.330	-0.759	0.05%	0.06%	0.10%	0.10%	-0.08%	-0.61%	-6.93%
RD	48.80%	112.20%	0.03%	0.08%	0.15%	0.18%	0.37%	0.51%	1.41%
ECC	0.068	0.075	0.00%	0.00%	0.00%	0.00%	0.00%	-0.06%	-0.22%
EP	0.018	0.028	-0.01%	-0.01%	-0.02%	-0.02%	0.01%	-0.01%	0.03%
FCA	0.115	0.184	-0.02%	-0.03%	-0.05%	-0.05%	0.04%	0.22%	1.23%
F1X	0.097	0.168	-0.01%	-0.01%	-0.03%	-0.03%	-0.02%	-0.75%	-0.64%
CC.N	3.266	3.981	0.00%	0.00%	0.00%	0.00%	0.00%	-0.21%	-0.78%
dVC.N	4.265	5.720	0.03%	0.04%	0.06%	0.08%	0.17%	0.19%	0.00%
ro.N	0.000	0.300	0.04%	0.05%	0.08%	0.07%	-0.06%	-0.36%	-2.48%

As can be seen from the above table, four control variables account for nearly all of the uncertainty in the determination of ROE. These are (1) the consumer discount rate (RD), (2) the industry elasticity of demand with respect to price (IPE), (3) fixed one-time costs (F1X), and (4) the elasticity curve shape parameter (ro.N). The reasons that these four variables are important are discussed below.

5.4.2 Alternative Scenarios

The sensitivity analysis shows that both price and operating cost elasticities (the latter being derived from the discount rate) play crucial roles in determining the model's output. These are both industry elasticities as opposed to single-firm elasticities; this means they measure the effect on demand of a change in price by all firms and a change in operating cost of all room air conditioners. The estimates of standard errors that 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, six alternative scenarios have been run. The six scenarios include low and high price elasticity scenarios, a constant shipments scenario (i.e., industry price and operating cost elasticity set to zero), high and low discount rate scenarios (i.e., high and low operating cost scenarios), and a low discount rate and high price elasticity scenario. Tables 5.4 through 5.9 show the results of running these six scenarios for the room air conditioner manufacturing industry.

In these alternative scenarios, note the impact of a change in the discount rate. A high RD input value lowers ROE, and a lower RD value increases ROE. Because markup is determined by price elasticity, it will tend to change as the ratio of price to operating cost changes. Standards will always increase this ratio, which decreases markup. This effect is strongest when appliance demand is relatively elastic with respect to operating cost. That is, a more elastic operating cost elasticity will result in a greater decrease in markup under standards, resulting in a greater decrease in profitability.

The other tables show that increasing price elasticity also tends to lower ROE. This effect is probably due to the greater decline in shipments when price elasticity is greater.

The shape of the demand curve parameter (α) plays a role under certain circumstances. The demand function is specified as a function of life-cycle cost (i.e., of purchase price and operating cost). If purchase price plays a relatively large role in the demand function, then demand is less sensitive to changes in the shape parameter since in the limit, demand would be a function of purchase price. Hence the shape parameter plays a larger role when operating cost and price play relatively equal roles in determining life-cycle cost. Also, it depends on how much of a change in operating costs results from a particular standards level under consideration. This is because a large change in operating cost will shift demand to a very different part of the demand curve.

The percentage of fixed costs (FCA) is important because of its role in the model. It determines the LBL-MIM's estimate of the markup over variable cost, which, in turn, determines the firm's ability to pass on various combinations of fixed and variable costs. For a more detailed explanation, see Volume A, Appendix C.

5.4.3 Monte Carlo Analysis

The Monte Carlo approach is described in Volume A, Chapter 3, Section 3.3.4.3, and the standard errors it generates are reported in the output tables. Table 5.10 shows the control panels from two Monte Carlo runs which were selected because they show a decrease in long-run ROE. Both Monte Carlo runs were done on standards level 2. In the first run, we see how large increases in the four highlighted variables are the primary factors in reducing ROE. In the second, increases in price elasticity, one-time costs, and the demand curve shape parameter with a smaller increase in the discount rate reduce ROE despite a small decrease in fixed costs.

Table 5.4 Room Air Conditioner Output Table: Low Industry Price Elasticity Scenario

	1996 BASE	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
Shipments (in Mil)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
% change		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%
S.E.		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Price	\$299.75	\$300.25	\$303.39	\$307.28	\$309.36	\$327.09	\$358.16	\$552.69
% change		0.17%	1.22%	2.51%	3.21%	9.12%	19.49%	84.38%
S.E.		0.50%	0.91%	1.23%	1.52%	3.36%	5.64%	22.03%
Revenue (in \$M)	298.52	299.02	302.15	306.02	308.09	325.75	356.69	550.39
% change		0.17%	1.22%	2.51%	3.21%	9.12%	19.49%	84.37%
S.E.		0.50%	0.91%	1.23%	1.52%	3.36%	5.64%	22.02%
Net Income (in \$M)	17.0	16.84	16.81	16.67	16.70	17.30	17.82	31.94
Difference		-0.16	-0.19	-0.33	-0.30	0.29	0.81	14.93
S.E.		0.182	0.29	0.37	0.38	0.89	2.43	13.30
ROE	8.52%	8.44%	8.42%	8.32%	8.33%	8.64%	8.28%	11.94%
Difference		-0.08%	-0.10%	-0.20%	-0.18%	0.12%	-0.24%	3.42%
S.E.		0.09%	0.14%	0.18%	0.19%	0.45%	1.14%	4.97%

Table 5.5 Room Air Conditioner Output Table: High Industry Price Elasticity Scenario

	1996 BASE	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
Shipments (in Mil)	1.00	1.01	1.01	1.02	1.02	0.99	0.94	0.68
% change		0.65%	0.84%	1.39%	1.33%	-1.00%	-6.03%	-31.95%
S.E.		0.37%	0.60%	0.87%	1.06%	2.13%	3.35%	7.05%
Price	\$299.75	\$300.25	\$303.39	\$307.28	\$309.36	\$327.09	\$358.16	\$552.68
% change		0.17%	1.22%	2.51%	3.21%	9.12%	19.49%	84.38%
S.E.		0.55%	0.88%	1.26%	1.54%	3.29%	5.98%	24.95%
Revenue (in \$M)	300.90	303.36	307.11	312.74	314.69	325.06	337.85	377.56
% change		0.82%	2.06%	3.94%	4.58%	8.03%	12.28%	25.48%
S.E.		0.18%	0.27%	0.38%	0.46%	0.87%	1.42%	8.27%
Net Income (in \$M)	17.32	17.42	17.45	17.54	17.55	17.22	15.26	3.73
Difference		0.10	0.13	0.22	0.23	-0.11	-2.06	-13.59
S.E.		0.15	0.20	0.29	0.33	0.53	2.30	12.87
ROE	8.61%	8.60%	8.60%	8.57%	8.58%	8.61%	7.45%	1.81%
Difference		-0.01%	-0.01%	-0.04%	-0.03%	0.00%	-1.17%	-6.80%
S.E.		0.07%	0.10%	0.13%	0.16%	0.25%	1.16%	6.63%

Table 5.6 Room Air Conditioner Output Table: Constant Shipments Scenario

	1996 BASE	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
Shipments (in Mil)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
% change		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
S.E.		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Price	\$299.75	\$300.25	\$303.39	\$307.28	\$309.36	\$327.09	\$358.16	\$552.69
% change		0.17%	1.22%	2.51%	3.21%	9.12%	19.49%	84.38%
S.E.		0.49%	0.84%	1.24%	1.48%	3.37%	5.70%	22.22%
Revenue (in \$M)	298.52	299.02	302.15	306.02	308.09	325.75	356.69	550.42
% change		0.17%	1.22%	2.51%	3.21%	9.12%	19.49%	84.38%
S.E.		0.49%	0.84%	1.24%	1.48%	3.37%	5.70%	22.22%
Net Income (in \$M)	17.01	16.84	16.81	16.67	16.70	17.30	17.82	31.94
Difference		-0.16	-0.20	-0.33	-0.31	0.30	0.82	14.94
S.E.		0.17	0.23	0.35	0.41	0.94	2.46	11.45
ROE	8.52%	8.44%	8.42%	8.32%	8.33%	8.64%	8.28%	11.94%
Difference		-0.08%	-0.10%	-0.20%	-0.18%	0.12%	-0.24%	3.42%
S.E.		0.08%	0.12%	0.17%	0.20%	0.47%	1.15%	4.19%

Table 5.7 Room Air Conditioner Output Table: Low Discount Rate Scenario

	1996 BASE	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
Shipments (Mil)	0.99	1.00	1.00	1.00	1.00	0.99	0.96	0.82
% change		0.32%	0.42%	0.69%	0.66%	-0.50%	-3.06%	-17.51%
S.E.		0.17%	0.29%	0.46%	0.53%	1.09%	1.62%	3.94%
Price	\$299.75	\$300.25	\$303.39	\$307.28	\$309.36	\$327.09	\$358.16	\$552.68
% change		0.17%	1.22%	2.51%	3.21%	9.12%	19.49%	84.38%
S.E.		0.49%	0.86%	1.36%	1.57%	3.33%	5.39%	22.46%
Revenue (in \$M)	299.70	301.18	304.62	309.36	311.37	325.41	347.14	455.87
% change		0.49%	1.64%	3.22%	3.89%	8.58%	15.83%	52.11%
S.E.		0.32%	0.57%	0.88%	1.02%	2.09%	3.21%	11.68%
Net Income (\$M)	17.16	17.12	17.12	17.10	17.12	17.25	16.52	16.51
Difference		-0.03	-0.03	-0.05	-0.04	0.09	-0.64	-0.65
S.E.		0.11	0.15	0.30	0.22	0.44	1.96	10.45
ROE	8.56%	8.52%	8.51%	8.45%	8.46%	8.62%	7.87%	7.05%
Difference		-0.04%	-0.06%	-0.12%	-0.11%	0.06%	-0.70%	-1.51%
S.E.		0.07%	0.09%	0.17%	0.13%	0.28%	0.99%	4.59%

Table 5.8 Room Air Conditioner Output Table: High Discount Rate Scenario

	1996 BASE	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
Shipments (in Mil)	0.99	0.99	0.99	0.99	0.98	0.96	0.94	0.80
% change		-0.03%	-0.35%	-0.73%	-0.94%	-2.78%	-5.75%	-19.01%
S.E.		0.17%	0.29%	0.43%	0.55%	1.13%	1.63%	3.66%
Price	\$300.45	\$301.24	\$304.81	\$309.35	\$311.66	\$330.70	\$363.62	\$567.52
% change		0.26%	1.45%	2.96%	3.73%	10.07%	21.02%	88.89%
S.E.		0.53%	0.89%	1.36%	1.77%	4.01%	6.77%	29.14%
Revenue (in \$M)	298.16	298.86	301.44	304.76	306.37	319.07	340.11	456.14
% change		0.24%	1.10%	2.21%	2.75%	7.01%	14.07%	52.99%
S.E.		0.35%	0.59%	0.90%	1.16%	2.59%	4.32%	17.99%
Net Income (in \$M)	17.33	17.34	17.46	17.59	17.67	18.34	18.24	22.48
Difference		0.01	0.13	0.26	0.35	1.01	0.91	5.15
S.E.		0.12	0.33	0.69	0.98	1.95	5.53	27.06
ROE	8.71%	8.72%	8.80%	8.87%	8.93%	9.44%	8.97%	9.77%
Difference		0.01%	0.09%	0.16%	0.22%	0.73%	0.26%	1.06%
S.E.		0.07%	0.18%	0.37%	0.54%	1.09%	2.87%	12.27%

Table 5.9 Room Air Conditioner Output Table: Low Discount Rate and High Price Elasticity Scenario

	1996 BASE	Level 1	Level 2	Level 3	Level 4	Level 6	Level 7	Level 8
Shipments (Mil)	1.11	1.17	1.24	1.37	1.41	1.54	1.63	1.35
% change		5.61%	12.08%	23.76%	27.20%	39.14%	46.70%	21.26%
S.E.		0.65%	1.54%	3.84%	4.77%	8.20%	11.54%	16.81%
Price	\$298.72	\$298.82	\$301.33	\$304.29	\$306.04	\$321.87	\$350.27	\$531.25
% change		0.03%	0.87%	1.86%	2.45%	7.75%	17.26%	77.84%
S.E.		0.57%	1.06%	1.73%	2.14%	3.35%	5.53%	19.83%
Revenue (in \$M)	331.41	350.12	374.70	417.81	431.88	496.86	570.07	714.70
% change		5.64%	13.06%	26.07%	30.32%	49.92%	72.01%	115.65%
S.E.		0.27%	0.75%	2.29%	2.81%	5.99%	8.89%	9.53%
Net Income (\$M)	20.78	22.71	24.94	29.00	30.18	34.17	40.15	44.43
Difference		1.93	4.16	8.22	9.40	13.39	19.37	23.65
S.E.		0.75	1.47	3.30	3.10	4.40	5.94	13.14
ROE	9.37%	9.71%	10.05%	10.58%	10.72%	11.12%	11.86%	13.23%
Difference		0.34%	0.69%	1.22%	1.35%	1.75%	2.49%	3.86%
S.E.		0.32%	0.60%	1.33%	1.18%	1.60%	1.78%	2.76%

Table 5.10 Room Air Conditioner Monte Carlo Runs: Searching for Low ROE

ROOM AIR CONDITIONERS CONTROL FACTORS		Scenario: Primary		Standard Level = 6		
		Input Value	Cntrl	Vari- ation	Progrm Value	Name
Price Elasticity		-0.330	2.64	100%	-2.973	IPE
Consumer Discount Rate		48.80%	0.43	100%	69.68%	RD
Equity Cost of Capital		0.068	-1.11	10%	0.061	ECC
Economic Profit		0.018	-1.09	1%	0.008	EP
L-R Fixed Part of Costs & Assets		0.115	1.67	50%	0.253	FCA
L-R Fixed Part of 1-X Cap. Cost		0.071	-0.01	60%	0.071	FIX
One-Time Capital Costs		7.353	1.11	20%	9.154	CC.N
Unit Variable Cost Increase		\$29.85	2.00	30%	53.648	dVC.N
Elasticity Curve Parameter		0.000	-0.93	30%	-0.278	ro.N
Short Run Price Response to Demand		0.157	1.61	76%	1.331	SRPR
		NAECA	NEW		PRVIOUS	NEW
SUMMARY		BASE	L-RUN	CHANGE	CHANGE	S-RUN
Shipments		1.02	0.57	-43.74%	0.69%	0.98
Price		\$299.15	\$382.93	28.01%	2.51%	\$373.88
Revenue (in \$M)		303.94	218.87	-27.99%	3.22%	365.73
Net Income		14.30	-1.43	-15.73	-0.06	26.80
ROE		7.03%	-1.19%	-8.22%	-0.12%	22.30%
08-Sep-92		15:48	Trys =		8.00	
ROOM AIR CONDITIONERS CONTROL FACTORS		Scenario: Primary		Standard Level = 6		
		Input Value	Cntrl	Vari- ation	Progrm Value	Name
Price Elasticity		-0.330	1.15	100%	-0.859	IPE
Consumer Discount Rate		48.80%	0.91	100%	104.39%	RD
Equity Cost of Capital		0.068	0.65	10%	0.073	ECC
Economic Profit		0.018	-1.17	1%	0.007	EP
L-R Fixed Part of Costs & Assets		0.115	0.86	50%	0.172	FCA
L-R Fixed Part of 1-X Cap. Cost		0.071	0.92	60%	0.119	FIX
One-Time Capital Costs		7.353	-0.86	20%	6.198	CC.N
Unit Variable Cost Increase		\$29.85	0.51	30%	34.706	dVC.N
Elasticity Curve Parameter		0.000	2.23	30%	0.668	ro.N
Short Run Price Response to Demand		0.157	0.95	76%	0.557	SRPR
		NAECA	NEW		PRVIOUS	NEW
SUMMARY		BASE	L-RUN	CHANGE	CHANGE	S-RUN
Shipments		0.99	0.94	-5.60%	-0.50%	0.96
Price		\$300.01	\$330.33	10.11%	9.12%	\$323.54
Revenue (in \$M)		298.30	310.06	3.94%	8.58%	310.33
Net Income		15.68	12.10	-3.58	0.10	8.50
ROE		7.87%	6.40%	-1.47%	0.06%	4.49%
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CHAPTER 6. IMPACTS OF STANDARDS ON ELECTRIC UTILITIES: ROOM AIR CONDITIONERS

6.1 INTRODUCTION

Appliance efficiency standards 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 standard levels. The fourth section presents the results of the revenue loss calculation. More details on methodology may be found in Appendix E of Volume A of this Technical Support Document.

6.2 AVOIDED ENERGY AND AVOIDED RELIABILITY COSTS

Figure 6.1 shows avoided energy and reliability costs for electricity savings from room air conditioners (RACs). These figures show the sum of avoided costs for the base-, high-, and low-energy price cases.¹ The value per million Btu (MMBtu) of avoided reliability costs is the same in all three energy price cases. The avoided fuel and capital component depends on fuel prices, and varies among the three cases. As explained in Appendix E of Volume A, this component implicitly contains the costs avoided when baseload power plants are deferred or canceled (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. They are used in the LBL-REM to value electricity savings from the societal perspective.

6.3 PEAK LOAD AND CAPACITY REDUCTIONS

Table 6.1 shows peak load reductions for RACs for the relevant standard levels. Table 6.2 shows capacity savings for RACs for the relevant standard levels. The base case peak load in the second column of Table 6.1 represents coincident peak load of all such appliances in the residential sector.

¹ Fuel price forecasts for the period 1990 to 2000 are taken from the DOE/EIA *Annual Energy Outlook 1991* (DOE/EIA-0383(91)). The forecasts for years after 2000 were linearly extrapolated using the methodology described in Volume A. The high (low) energy price case is derived by increasing (decreasing) the reference case AEO fuel price forecasts for gas and coal by 5%.

Figure 6.1 Utility Avoided Costs for RACs

Table 6.1 Peak Demand Reductions (GW) - RACs

Year	Peak Load	Peak Demand Savings						
		Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
1996	40.4	0.1	0.3	0.6	0.7	1.1	1.4	2.1
1997	40.9	0.2	0.4	0.8	1.0	1.5	2.0	3.0
1998	41.5	0.2	0.5	1.1	1.2	1.9	2.5	3.8
1999	42.0	0.3	0.6	1.3	1.5	2.2	3.0	4.6
2000	42.5	0.3	0.8	1.5	1.7	2.6	3.4	5.2
2001	43.0	0.4	0.9	1.7	1.9	2.9	3.9	5.9
2002	43.5	0.4	1.0	1.9	2.1	3.3	4.3	6.5
2003	44.0	0.5	1.1	2.1	2.4	3.6	4.7	7.0
2004	44.6	0.5	1.2	2.3	2.6	3.9	5.1	7.6
2005	45.3	0.6	1.3	2.5	2.8	4.2	5.6	8.2
2006	45.9	0.6	1.4	2.7	3.0	4.5	5.9	8.7
2007	46.5	0.6	1.5	2.8	3.2	4.8	6.3	9.1
2008	47.2	0.7	1.5	3.0	3.4	5.0	6.6	9.5
2009	47.9	0.7	1.6	3.1	3.5	5.2	6.8	9.9
2010	48.6	0.7	1.6	3.2	3.6	5.3	7.0	10.1
2011	49.2	0.7	1.7	3.2	3.6	5.4	7.1	10.3
2012	49.8	0.7	1.7	3.2	3.7	5.5	7.2	10.4
2013	50.4	0.8	1.7	3.3	3.7	5.5	7.2	10.6
2014	50.9	0.8	1.7	3.3	3.7	5.5	7.3	10.7
2015	51.4	0.8	1.7	3.3	3.8	5.6	7.3	10.8
2016	51.8	0.8	1.7	3.3	3.8	5.6	7.4	10.9
2017	52.3	0.8	1.8	3.4	3.8	5.7	7.5	11.0
2018	52.7	0.8	1.7	3.4	3.8	5.7	7.5	11.0
2019	53.1	0.8	1.7	3.4	3.8	5.7	7.5	11.1
2020	53.6	0.8	1.7	3.4	3.8	5.7	7.6	11.2
2021	54.0	0.8	1.7	3.4	3.8	5.7	7.6	11.2
2022	54.5	0.8	1.7	3.3	3.8	5.7	7.6	11.3
2023	55.0	0.8	1.7	3.3	3.8	5.7	7.6	11.4
2024	55.4	0.8	1.6	3.3	3.7	5.7	7.6	11.4
2025	55.8	0.7	1.5	3.2	3.6	5.6	7.6	11.4
2026	56.2	0.7	1.5	3.1	3.5	5.5	7.5	11.3
2027	56.6	0.7	1.4	3.0	3.4	5.5	7.4	11.3
2028	56.9	0.6	1.3	2.9	3.3	5.4	7.4	11.3
2029	57.2	0.6	1.2	2.8	3.2	5.3	7.3	11.2
2030	57.5	0.6	1.1	2.7	3.1	5.2	7.2	11.2

Table 6.2 Capacity Savings (GW) - RACs

Year	Capacity Savings						
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
1996	0.1	0.2	0.5	0.6	0.9	1.2	1.8
1997	0.1	0.3	0.7	0.8	1.2	1.6	2.5
1998	0.2	0.4	0.9	1.0	1.6	2.1	3.2
1999	0.3	0.8	1.5	1.8	2.7	3.6	5.5
2000	0.4	0.9	1.8	2.0	3.1	4.1	6.3
2001	0.4	1.0	2.0	2.3	3.5	4.6	7.0
2002	0.5	1.1	2.3	2.6	3.9	5.2	7.7
2003	0.6	1.3	2.5	2.8	4.3	5.7	8.5
2004	0.6	1.4	2.7	3.1	4.7	6.2	9.1
2005	0.7	1.5	3.0	3.4	5.1	6.7	9.8
2006	0.7	1.6	3.2	3.6	5.4	7.1	10.4
2007	0.8	1.8	3.4	3.9	5.7	7.5	11.0
2008	0.8	1.8	3.6	4.0	6.0	7.9	11.5
2009	0.9	1.9	3.7	4.2	6.2	8.1	11.8
2010	0.9	2.0	3.8	4.3	6.4	8.3	12.1
2011	0.9	2.0	3.9	4.3	6.5	8.5	12.4
2012	0.9	2.0	3.9	4.4	6.5	8.6	12.5
2013	0.9	2.0	3.9	4.4	6.6	8.7	12.7
2014	0.9	2.1	4.0	4.5	6.7	8.7	12.8
2015	0.9	2.1	4.0	4.5	6.7	8.8	12.9
2016	0.9	2.1	4.0	4.5	6.8	8.9	13.0
2017	0.9	2.1	4.1	4.6	6.8	9.0	13.1
2018	0.9	2.1	4.0	4.6	6.8	9.0	13.2
2019	0.9	2.1	4.0	4.6	6.9	9.0	13.3
2020	0.9	2.1	4.0	4.6	6.9	9.1	13.4
2021	1.0	2.0	4.0	4.6	6.9	9.1	13.5
2022	1.0	2.0	4.0	4.5	6.9	9.1	13.6
2023	0.9	2.0	4.0	4.5	6.9	9.2	13.6
2024	0.9	1.9	3.9	4.5	6.8	9.1	13.7
2025	0.9	1.8	3.8	4.4	6.8	9.1	13.6
2026	0.8	1.8	3.7	4.2	6.6	9.0	13.6
2027	0.8	1.7	3.6	4.1	6.5	8.9	13.6
2028	0.8	1.6	3.5	4.0	6.4	8.8	13.5
2029	0.7	1.5	3.4	3.9	6.3	8.7	13.5
2030	0.7	1.4	3.3	3.8	6.2	8.7	13.4

The total peak demand and the savings are calculated using the appropriate conservation load factors, a T&D loss factor of 1.075, and estimates of energy consumption calculated using the LBL-REM. Capacity savings are peak load savings in regions that need additional capacity, multiplied by 1.2 to account for reserve margin needed for adequate reliability. The amount of capacity saved can be somewhat less than the peak demand savings in years before 1999 because capacity savings are only counted in regions that need capacity. After 1998, capacity savings consistently exceed peak load savings by the reserve margin of 20% (numbers may not exactly correspond to this rule because of rounding errors).

Peak demand reductions from the standards for RACs range from 0.3 to 5.2 GW in 2000, and from 0.6 to 11.2 GW in 2030. Capacity savings for RACs range from 0.4 to 6.3 GW in 2000, and from 0.7 to 13.4 GW in 2030.

6.4 REVENUE LOSSES

Appliance standards allow utilities to avoid the variable costs of generating electricity, but standards also reduce electricity sales. In a 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 standards 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, use the most current information on the impacts of appliance efficiency standards.

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 standards 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 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 standards, 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 standards 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-standard sales forecast, this case is included as an absolute upper bound. Figure 6.2 shows annual revenue losses and avoided costs over time for level 5 standards, and Table 6.3 shows net revenue losses for all standards levels. Note that negative revenue losses signify net *increases* in utility revenues. Cumulative net revenue increases for RACs range from \$0.7 to 10.8 billion.

Figure 6.2 Revenue Reductions and Avoided Costs for RACs

Table 6.3 Net Revenue Losses - RACs (Million 1990 Dollars)

Year	Net Revenue Losses						
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
1996	2	4	9	10	15	20	30
1997	2	5	10	12	18	24	37
1998	3	6	12	13	20	27	42
1999	-2	-6	-11	-13	-20	-26	-40
2000	-3	-8	-15	-17	-27	-35	-54
2001	-5	-10	-20	-23	-35	-47	-71
2002	-6	-13	-26	-30	-45	-60	-90
2003	-7	-17	-33	-37	-56	-74	-111
2004	-9	-20	-40	-46	-69	-90	-133
2005	-11	-25	-48	-55	-82	-107	-158
2006	-12	-28	-55	-62	-92	-121	-177
2007	-14	-32	-61	-69	-103	-135	-198
2008	-16	-35	-68	-76	-114	-149	-217
2009	-17	-38	-74	-83	-124	-162	-235
2010	-18	-41	-79	-89	-133	-174	-253
2011	-20	-44	-85	-96	-143	-188	-274
2012	-21	-48	-91	-103	-153	-201	-294
2013	-23	-51	-97	-110	-164	-214	-313
2014	-24	-54	-103	-116	-173	-228	-333
2015	-25	-57	-109	-123	-183	-241	-353
2016	-26	-60	-115	-130	-193	-254	-373
2017	-28	-63	-121	-137	-204	-268	-393
2018	-29	-65	-126	-142	-213	-281	-413
2019	-31	-67	-131	-148	-223	-293	-433
2020	-32	-70	-136	-154	-232	-306	-453
2021	-33	-72	-141	-160	-241	-319	-473
2022	-35	-73	-146	-165	-250	-332	-493
2023	-35	-75	-150	-170	-259	-345	-513
2024	-35	-75	-153	-174	-266	-355	-531
2025	-35	-74	-154	-175	-271	-364	-548
2026	-34	-73	-154	-176	-275	-372	-564
2027	-34	-71	-154	-176	-280	-380	-579
2028	-33	-69	-154	-176	-283	-388	-595
2029	-32	-66	-153	-176	-287	-395	-610
2030	-31	-64	-152	-176	-290	-402	-625
Total	-711	-1547	-3127	-3548	-5430	-7237	-10789

The values in Table 6.3 show changes in utility revenues, assuming no regulatory adjustment. Because the avoided costs for RACs are higher than the lost revenues, net utility revenues will actually increase, thereby *decreasing* rates. When regulators adjust rates to reflect these higher net revenues, rates will decrease over the base case forecast, and utilities will no longer gain revenue. Total residential rates would decrease 0% and 0.1% (0.000¢/kWh and 0.01¢/kWh) in 2000 and 2005, respectively, if RACs are subject to level 5 standards and regulators only change residential rates to compensate for any increase in revenue.

Table 6.4 shows the present value of net revenue losses at a 5% real utility discount rate for all standard 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 6.4 Present Value of Revenue Losses - RACs (Million 1990 Dollars)

Regulatory Lag	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
None	0	0	0	0	0	0	0
1996-2001	1	2	5	6	9	12	18
1996-2030	-185	-407	-808	-916	-1389	-1842	-2731

For RACs, the present value of net lost revenues may range from \$1 to 18 million for a five-year lag. However, if regulators did not adjust rates, utilities would actually receive increased revenues of as much as \$2.7 billion. The present values over the period 1996 to 2030 also represent the rate decreases needed over this period to compensate for increased revenues, assuming that regulators adjust them immediately.

6.5 SENSITIVITY ANALYSIS

Tables 6.5 and 6.6 show the peak demand reductions and capacity savings for the sensitivity cases. Table 7.6 shows the present value of net lost revenues for the same sensitivity cases. The assumptions for the sensitivity cases are the same for those for previous tables, and note again that negative lost revenues indicate net increases to utility revenues.

Table 6.5 Peak Demand Reductions (GW) - RACs (Sensitivity Cases)

Year	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
1996	1.0	1.1	1.1	1.1	0.9	0.9
2000	2.4	2.7	2.7	2.6	2.1	1.1
2010	5.0	5.5	5.5	5.4	2.6	3.4
2020	4.7	6.1	6.2	5.4	0.4	3.1
2030	4.6	6.6	6.2	4.8	0.0	2.4

Table 6.6 Capacity Savings (GW) - RACs (Sensitivity Cases)

Year	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
1996	0.8	1.0	1.0	0.9	0.8	0.8
2000	2.9	3.3	3.2	3.1	2.5	2.5
2010	5.9	6.6	6.6	6.5	3.1	4.1
2020	5.7	7.3	7.4	6.5	0.5	3.8
2030	5.5	7.9	7.4	5.8	0.0	2.8

Table 6.7 Present Value of Net Lost Revenues (Million 1990 \$) - RACs (Sensitivity Cases)

Regulatory Lag	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
None	0	0	0	0	0	0
1996-2001	9	9	4	16	9	10
1996-2030	-1221	-1506	-1495	-1356	-369	-819

CHAPTER 7: ENVIRONMENTAL EFFECTS

7.1 INTRODUCTION

The environmental effects from a range of new candidate energy conservation standards for room air conditioners are presented here. The results are presented for each potential standard level. Each measure of possible environmental change is an alternative action, and it is compared to what is expected to happen if no new standards for room air conditioners were finalized, i.e., the "no action" alternative.

The environmental concern addressed is emissions from fossil-fueled electricity generation. All of the design options for room air conditioners result in decreased electricity use and, therefore, a reduction of power plant emissions. The proposed efficiency standards will 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, or SO₂. Reductions of nitrogen oxides and carbon dioxide also occur and are listed by weight of NO_x and CO₂, respectively. CO₂ emissions from fossil-fuel burning is considered an environmental hazard because it contributes to the "greenhouse effect" by trapping heat energy from the earth that is emitted as infrared radiation. The "greenhouse effect" is expected to gradually raise the mean global temperature.

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

7.2 RESULTS

The following tabular results indicate what changes can be brought about in the amounts of emitted CO₂, SO₂, and NO_x by imposing efficiency standards for room air conditioners. A table is presented for each of the appliance's trial standard levels. Each table details the changes that occur to each of the three emissions (i.e., CO₂, SO₂, and NO_x) through the imposition of a specific trial standard level. Each table includes the following information for a specific year between 1996 and 2030: the amount of emission abated from power plant generation, the amount abated from in-home 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 1996 and 2030).

Decreases in the amounts of CO₂, SO₂, and NO_x emitted at trial standards levels 1 through 7 are summarized in Tables 7.1 through 7.7.

7.2.1 Sulfur and Nitrogen Oxide Emissions

SO₂ emissions would be decreased by a cumulative total of up to 0.78 million tons between 1996 and 2030 in the level 7 scenario. In the year 1996, decreases in SO₂ will represent about 0.11% of the SO₂ emissions estimated to come from power plants in that year. In the year 2030, decreases in SO₂ emissions will represent about 0.26% of the SO₂ emissions estimated to come from power plants in that year. Because of provisions in the Clean Air Act Amendments (Pub. L. 101-549, November 15, 1990), the possible reductions of SO₂ that are caused by standards can be earned as credits by the utility realizing the reductions. To the extent SO₂ credits are used for future emissions, the net effect on SO₂ emissions from standards would be only a postponement of those SO₂ emissions.

Level 7 design changes to room air conditioners would result in an estimated decrease in NO_x emissions of 0.70 million tons between 1996 and 2030. NO_x decreases would represent 0.11% and 0.26% of the NO_x emissions estimated to come from power plants in the years 1996 and 2030, respectively.

7.2.2 Carbon Dioxide Emissions

The cumulative reduction in CO₂ emissions from level 7 design changes is 360 million tons of CO₂. For the year 1996, the estimated CO₂ reduction is 2496 thousand tons of CO₂ or about 0.11% of estimated U.S. total CO₂ emissions in 1996. For the year 2030, the estimated CO₂ reduction is 12,253 thousand tons of CO₂ or about 0.26% of estimated U.S. total CO₂ emissions in 2030.

Table 7.1
Reduction of Pollutants for Room Air Conditioners - Level One

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	172	0	172	0.01%
2000	419	0	419	0.02%
2005	676	0	676	0.02%
2010	765	0	765	0.02%
2015	931	0	931	0.03%
2020	928	0	928	0.02%
2025	835	0	835	0.02%
2030	580	0	580	0.01%

Cumulative CO2 reduction, 1996-2030 = 24 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	966	0	966	0.01%
2000	1,505	0	1,505	0.02%
2005	2,054	0	2,054	0.02%
2010	1,996	0	1,996	0.02%
2015	1,957	0	1,957	0.03%
2020	1,568	0	1,568	0.02%
2025	1,095	0	1,095	0.02%
2030	579	0	579	0.01%

Cumulative SO2 reduction, 1996-2030 = 52,274 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	%U.S. NOx Power Plant Emissions
1996	607	0	607	0.01%
2000	1,121	0	1,121	0.02%
2005	1,653	0	1,653	0.02%
2010	1,735	0	1,735	0.02%
2015	1,814	0	1,814	0.03%
2020	1,568	0	1,568	0.02%
2025	1,200	0	1,200	0.02%
2030	712	0	712	0.01%

Cumulative NOx reduction, 1996-2030 = 46,839 tons

Table 7.2
Reduction of Pollutants for Room Air Conditioners - Level Two

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	344	0	344	0.02%
2000	838	0	838	0.03%
2005	1,436	0	1,436	0.05%
2010	1,785	0	1,785	0.06%
2015	1,946	0	1,946	0.05%
2020	1,939	0	1,939	0.05%
2025	1,670	0	1,670	0.04%
2030	1,325	0	1,325	0.03%

Cumulative CO2 reduction, 1996-2030 = 53 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	1,933	0	1,933	0.02%
2000	3,011	0	3,011	0.03%
2005	4,365	0	4,365	0.05%
2010	4,657	0	4,657	0.06%
2015	4,091	0	4,091	0.05%
2020	3,278	0	3,278	0.05%
2025	2,190	0	2,190	0.04%
2030	1,323	0	1,323	0.03%

Cumulative SO2 reduction, 1996-2030 = 115,744 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	%U.S. NOx Power Plant Emissions
1996	1,213	0	1,213	0.01%
2000	2,241	0	2,241	0.03%
2005	3,512	0	3,512	0.05%
2010	4,047	0	4,047	0.06%
2015	3,793	0	3,793	0.05%
2020	3,278	0	3,278	0.05%
2025	2,399	0	2,399	0.04%
2030	1,627	0	1,627	0.03%

Cumulative NOx reduction, 1996-2030 = 103,365 tons

Table 7.3
Reduction of Pollutants for Room Air Conditioners - Level Three

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	689	0	689	0.03%
2000	1,677	0	1,677	0.07%
2005	2,788	0	2,788	0.10%
2010	3,485	0	3,485	0.11%
2015	3,808	0	3,808	0.11%
2020	3,795	0	3,795	0.10%
2025	3,506	0	3,506	0.08%
2030	2,980	0	2,980	0.06%

Cumulative CO2 reduction, 1996-2030 = 105 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	3,866	0	3,866	0.03%
2000	6,022	0	6,022	0.07%
2005	8,473	0	8,473	0.10%
2010	9,093	0	9,093	0.11%
2015	8,005	0	8,005	0.11%
2020	6,413	0	6,413	0.10%
2025	4,598	0	4,598	0.08%
2030	2,978	0	2,978	0.06%

Cumulative SO2 reduction, 1996-2030 = 229,357 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. NOx Power Plant Emissions
1996	2,427	0	2,427	0.03%
2000	4,483	0	4,483	0.07%
2005	6,818	0	6,818	0.10%
2010	7,902	0	7,902	0.11%
2015	7,422	0	7,422	0.11%
2020	6,413	0	6,413	0.10%
2025	5,038	0	5,038	0.08%
2030	3,660	0	3,660	0.06%

Cumulative NOx reduction, 1996-2030 = 205,243 tons

Table 7.4
Reduction of Pollutants for Room Air Conditioners - Level Four

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	861	0	861	0.04%
2000	1,928	0	1,928	0.08%
2005	3,126	0	3,126	0.11%
2010	3,995	0	3,995	0.12%
2015	4,231	0	4,231	0.12%
2020	4,301	0	4,301	0.11%
2025	4,007	0	4,007	0.09%
2030	3,312	0	3,312	0.07%

Cumulative CO2 reduction, 1996-2030 = 119 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	4,832	0	4,832	0.04%
2000	6,925	0	6,925	0.08%
2005	9,500	0	9,500	0.11%
2010	10,424	0	10,424	0.12%
2015	8,894	0	8,894	0.12%
2020	7,268	0	7,268	0.11%
2025	5,255	0	5,255	0.09%
2030	3,308	0	3,308	0.07%

Cumulative SO2 reduction, 1996-2030 = 261,109 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	%U.S. NOx Power Plant Emissions
1996	3,033	0	3,033	0.04%
2000	5,155	0	5,155	0.08%
2005	7,644	0	7,644	0.11%
2010	9,059	0	9,059	0.12%
2015	8,246	0	8,246	0.12%
2020	7,268	0	7,268	0.11%
2025	5,758	0	5,758	0.09%
2030	4,067	0	4,067	0.07%

Cumulative NOx reduction, 1996-2030 = 233,507 tons

Table 7.5
Reduction of Pollutants for Room Air Conditioners - Level Five

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	1,291	0	1,291	0.06%
2000	2,935	0	2,935	0.12%
2005	4,731	0	4,731	0.17%
2010	5,950	0	5,950	0.18%
2015	6,262	0	6,262	0.17%
2020	6,409	0	6,409	0.16%
2025	6,261	0	6,261	0.14%
2030	5,630	0	5,630	0.12%

Cumulative CO2 reduction, 1996-2030 = 181' million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	7,249	0	7,249	0.06%
2000	10,538	0	10,538	0.12%
2005	14,379	0	14,379	0.17%
2010	15,525	0	15,525	0.18%
2015	13,163	0	13,163	0.17%
2020	10,831	0	10,831	0.16%
2025	8,211	0	8,211	0.14%
2030	5,624	0	5,624	0.12%

Cumulative SO2 reduction, 1996-2030 = 394,176 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	%U.S. NOx Power Plant Emissions
1996	4,550	0	4,550	0.06%
2000	7,845	0	7,845	0.12%
2005	11,569	0	11,569	0.17%
2010	13,492	0	13,492	0.18%
2015	12,204	0	12,204	0.17%
2020	10,831	0	10,831	0.16%
2025	8,996	0	8,996	0.14%
2030	6,913	0	6,913	0.12%

Cumulative NOx reduction, 1996-2030 = 353,124 tons

Table 7.6
Reduction of Pollutants for Room Air Conditioners - Level Six

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	1,636	0	1,636	0.07%
2000	3,689	0	3,689	0.15%
2005	6,168	0	6,168	0.22%
2010	7,820	0	7,820	0.24%
2015	8,293	0	8,293	0.23%
2020	8,432	0	8,432	0.21%
2025	8,348	0	8,348	0.19%
2030	7,865	0	7,865	0.16%

Cumulative CO2 reduction, 1996-2030 = 240 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	9,182	0	9,182	0.07%
2000	13,248	0	13,248	0.15%
2005	18,744	0	18,744	0.22%
2010	20,404	0	20,404	0.24%
2015	17,433	0	17,433	0.23%
2020	14,252	0	14,252	0.21%
2025	10,948	0	10,948	0.19%
2030	7,858	0	7,858	0.16%

Cumulative SO2 reduction, 1996-2030 = 520,335 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	%U.S. NOx Power Plant Emissions
1996	5,764	0	5,764	0.07%
2000	9,863	0	9,863	0.15%
2005	15,081	0	15,081	0.22%
2010	17,732	0	17,732	0.24%
2015	16,163	0	16,163	0.23%
2020	14,252	0	14,252	0.21%
2025	11,995	0	11,995	0.19%
2030	9,658	0	9,658	0.16%

Cumulative NOx reduction, 1996-2030 = 466,729 tons

Table 7.7
Reduction of Pollutants for Room Air Conditioners - Level Seven

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	2,496	0	2,496	0.11%
2000	5,785	0	5,785	0.23%
2005	9,125	0	9,125	0.32%
2010	11,390	0	11,390	0.35%
2015	12,101	0	12,101	0.34%
2020	12,564	0	12,564	0.32%
2025	12,688	0	12,688	0.29%
2030	12,253	0	12,253	0.26%

Cumulative CO2 reduction, 1996-2030 = 360 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	14,014	0	14,014	0.11%
2000	20,776	0	20,776	0.23%
2005	27,731	0	27,731	0.32%
2010	29,718	0	29,718	0.35%
2015	25,437	0	25,437	0.33%
2020	21,235	0	21,235	0.32%
2025	16,641	0	16,641	0.29%
2030	12,241	0	12,241	0.26%

Cumulative SO2 reduction, 1996-2030 = 777,408 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	%U.S. NOx Power Plant Emissions
1996	8,797	0	8,797	0.11%
2000	15,466	0	15,466	0.23%
2005	22,312	0	22,312	0.32%
2010	25,827	0	25,827	0.35%
2015	23,584	0	23,584	0.34%
2020	21,235	0	21,235	0.32%
2025	18,232	0	18,232	0.29%
2030	15,047	0	15,047	0.26%

Cumulative NOx reduction, 1996-2030 = 697,544 tons

APPENDIX A. ENGINEERING ANALYSIS - SUPPORTING DOCUMENTATION

A.1 ROOM AIR CONDITIONER SIMULATION MODEL

A.1.1 Introduction

The room air conditioner simulation model is a modified version of the Oak Ridge Heat Pump Design Model, Mark III version (23) (24). The Oak Ridge model is a comprehensive program for the simulation of an electrically driven, air-source heat pump. The simulation model is divided into two main parts: the high side and the low side. The high side includes models for the compressor, the condenser, and the expansion device. The low side includes only a model for the evaporator. The flow chart in Figure A.1 presents the solution logic of the Oak Ridge model. The model first performs a high-side balance based on calculating a mass flow rate through the expansion device that matches the one through the compressor. Once a high-side balance is achieved, a low-side balance is performed in which the evaporator model seeks an air inlet temperature that ensures the previous balance at the high side. Modifications were made to the simulation model in order to simulate the performance of room air conditioners (25). These modifications included the following: addition of routines to model subcoolers and condensate spray, elimination of the reversing valve model, modification of the capillary tube model, and addition of adjustment factors to model rifled (grooved) tubing. For further details on the simulation model and the modifications made to it, consult the references cited above. The remainder of this section will focus on the additional modifications incorporated into the simulation model in order to better predict the performance of room air conditioners.

Figure A.1 Solution Logic of the Oak Ridge Heat Pump Design Model

A.1.2 Simulation Model Modifications

There were several additional modifications made to the simulation model. Several of the modifications consisted of adding additional inputs to the simulation model so that quantities such as the compressor power, refrigerant mass flow rate, and air-side heat-transfer coefficients could be adjusted to equal measured test values. Minor modifications were also made to include additional values in the output. More involved changes were required of the compressor model and condensate spray routine. Following are the changes that were made to the modified Mark III version of the Oak Ridge Heat Pump Design Model.

Compressor Model

The compressor model is a map-based model. It is based on the use of compressor manufacturers' data (compressor maps) for a specific compressor. The model has built-in corrections to adjust for levels of refrigerant superheat in reciprocating compressors, which are different from those for which the maps were generated. The original authors of the simulation model contend that, although the model was written for reciprocating compressors, it should be easy to modify for use with rotary, screw, or centrifugal compressors.

Upon review of the compressor model, the built-in corrections for superheat were found to be inadequate for compressors other than reciprocating types. The correction equations were specifically derived to model a low-side cooled reciprocating compressor. They were based on calculating the enthalpy change from the compressor shell inlet to the compressor suction port. Since room air conditioners primarily use high-side cooled rotary compressors with an accumulator, the superheat correction scheme was modified. Modifications consisted of two primary changes: (1) calculation of map and actual suction port conditions directly from assumed temperature and pressure increases across the accumulator, and (2) calculation of the refrigerant mass flow rate correction factor based solely on the ratio of the map-to-actual specific volumes.

To incorporate temperature and pressure increases across the accumulator into the compressor model, compressor shell inlet conditions were assumed to exist at the accumulator inlet. In a high-side cooled rotary compressor, the suction port is practically located at the inlet to the compressor shell. Due to this condition, the suction port conditions were assumed to exist at the compressor shell inlet. Temperature and pressure increases of 5° F and 1 psi across the accumulator were used. These values were determined by compressor manufacturers and provided by the Association of Home Appliance Manufacturers (AHAM). The temperature and pressure values were input into the simulation model through the DATAIN subroutine and given the variable names TACCM and PACCM. To calculate the map and actual port conditions, the accumulator temperature and pressure increases were simply added to the pre-adjusted temperature and pressure values.

The refrigerant mass flow rate correction factor originally took the form:

$$XMRCOR = m_{actual} / m_{map} = 1.0 + (v_{map} / v_{actual} - 1.0) * F_v \quad (A.1)$$

where $XMRCOR$ is the refrigerant mass flow rate correction factor, m_{actual} is the refrigerant mass flow rate at actual conditions, m_{map} is the refrigerant mass flow rate at map conditions, v_{actual} is the specific volume of the refrigerant at actual conditions, v_{map} is the specific volume of the refrigerant at map conditions, and F_v is a volumetric efficiency correction factor. The new correction factor is based on representing the refrigerant mass flow rate as:

$$m = D S_{oper} n_{vol} / v \quad (A.2)$$

where m is the refrigerant mass flow rate, D is the piston displacement, S_{oper} is the motor speed, n_{vol} is the volumetric efficiency, and v is the specific volume. With the mass flow rate represented in this manner, the new correction factor takes the form:

$$XMRCOR = m_{actual} / m_{map} = (v_{map} n_{vol,act} S_{oper,act}) / (v_{actual} n_{vol,map} S_{oper,map}) \quad (A.3)$$

Assuming that the ratio of the actual-to-map volumetric efficiency and motor speed product is one, the correction factor simply becomes the ratio of the map-to-actual specific volumes. Thus, the new correction factor equation becomes:

$$XMRCOR = m_{actual} / m_{map} = v_{map} / v_{actual} \quad (A.4)$$

The ratio of the actual-to-map volumetric efficiency and motor speed product was assumed to be one because no other data was provided to indicate otherwise. Upon conferring with manufacturers, this assumption seemed to be reasonable.

Figures A.2 and A.3 contain listings of the original and modified versions of SUPCOR, the subroutine used for calculating the compressor power and refrigerant mass flowrate correction factors. Program lines that appear in bold in the modified version (Figure A.3) designate the changes that were made. Also note that the modified version has deleted several program lines that were used in the original version. For definitions of the variables that appear in the listings provided in Figures A.2 and A.3, please refer to the first reference cited in the introduction to this Appendix.

Figure A.2 Subroutine SUPCOR: Original Version

```

SUBROUTINE SUPCOR(SUCFAC,VOLFAC,TOLH,TOLS,TSICMP,
&    TSOCMP, HINCMP, SUPERB,POWPXM,POWCOR,XMRCOR)
C
C*** PURPOSE: TO CORRECT RECIPROCATING COMPRESSOR MAP-VALUES OF
C*** POWER CONSUMPTION AND MASS FLOW RATE TO ACCOUNT FOR SUCTION
C*** SUPERHEAT LEVELS DIFFERENT FROM THOSE FOR WHICH THE MAP
C*** WAS GENERATED.
C
    INTEGER FLAG
    TRICMB=TSICMP+SUPERB
    IF(SUPERB.LT.0.0) TRICMB=-SUPERB
    CALL SATPRP(TSICMP,PINCMP,VF,VG,HF,HFG,HG,SF,SG,FLAG)
    CALL VAPOR(TRICMB,PINCMP,X,HINBSE,Y,IERROR)
    DELHSP=SUCFAC*POWPXM
    DO 1 I=1,2
    HSUP=HINBSE
    IF(I.EQ.2) HSUP=HINCMP
    HSP=HSUP+DELHSP
    IF(HSP.GT.HG) GO TO 2
    XSP=(HSP-HF)/HFG
    SSP=SF+XSP*(SG-SF)
    VSP=VF+XSP*(VG-VF)
    TSP=TSICMP
    GO TO 3
2    CONTINUE
    CALL TRIAL(TSICMP,50.,PINCMP,3,HSP,TOLH,VSP,HSP,SSP,TSP,IERROR)
3    CONTINUE
    CALL SATPRP(TSOCMP,POUCMP,X,Y,HFO,HFGO,Z,SFO,SGO,FLAG)
    IF(SSP.GT.SGO) GO TO 4
    XOUT=(SSP-SFO)/(SGO-SFO)
    HOUISN=HFO+XOUT*HFGO
    GO TO 5
4    CONTINUE
    CALL TRIAL(TSOCMP,50.,POUCMP,4,SSP,TOLS,X,HOUISN,Y,Z,IERROR)
5    CONTINUE
    DELISN=HOUISN-HSP
    IF(I.NE.1) GO TO 1
    DELHSV=DELISN
    VSPSV=VSP
1    CONTINUE
    XMRCOR=1.+(VSPSV/VSP-1.)*VOLFAC
    POWCOR=XMRCOR*DELISN/DELHSV
    RETURN
    END

```

Figure A.3 Subroutine SUPCOR: Modified Version

```

      SUBROUTINE SUPCOR(TACCM,PACCM,TOLH,TOLS,TSICMP,
&      TSOCMP,TRICMP,SUPERB,POWPXM,POWCOR,XMRCOR)
C
C*** PURPOSE: TO CORRECT RECIPROCATING COMPRESSOR MAP-VALUES OF
C*** POWER CONSUMPTION AND MASS FLOW RATE TO ACCOUNT FOR SUCTION
C*** SUPERHEAT LEVELS DIFFERENT FROM THOSE FOR WHICH THE MAP
C*** WAS GENERATED.
C
      INTEGER FLAG
      TRICMB=TSICMP+SUPERB
      IF(SUPERB.LT.0.0) TRICMB=-SUPERB
      CALL SATPRP(TSICMP,PINCMP,VF,VG,HF,HFG,HG,SF,SG,FLAG)
      TSP=TRICMB+TACCM
      PSP=PINCMP+PACCM
      DO 1 I=1,2
      IF(I.EQ.2) GO TO 6
      GO TO 7
6      TSP=TRICMP+TACCM
7      CALL VAPOR(TSP,PSP,VSP,HSP,SSP,IERROR)
      IF(HSP.GT.HG) GO TO 3
      XSP=(HSP-HF)/HFG
      SSP=SF+XSP*(SG-SF)
      VSP=VF+XSP*(VG-VF)
      TSP=TSICMP
3      CONTINUE
      CALL SATPRP(TSOCMP,POUCMP,X,Y,HFO,HFGO,Z,SFO,SGO,FLAG)
      IF(SSP.GT.SGO) GO TO 4
      XOUT=(SSP-SFO)/(SGO-SFO)
      HOUISN=HFO+XOUT*HFGO
      GO TO 5
4      CONTINUE
      CALL TRIAL(TSOCMP,50.,POUCMP,4,SSP,TOLS,X,HOUISN,Y,Z,IERROR)
5      CONTINUE
      DELISN=HOUISN-HSP
      IF(I.NE.1) GO TO 1
      DELHSV=DELISN
      VSPSV=VSP
1      CONTINUE
      XMRCOR=VSPSV/VSP
      POWCOR=XMRCOR*DELISN/DELHSV
      RETURN
      END

```

Additional correction factors were added to the simulation model to further adjust the refrigerant mass flow rate and compressor power. After initial runs of the simulation model yielded results that differed from measured test data, additional correction factors were added to reduce the error between simulated and test results. The additional correction factors were input through the DATAIN subroutine and given the variable names COMPOWCF and XMSFLOCF. They were used to adjust the compressor power and mass flow rate directly after the original correction factors calculated by subroutine SUPCOR were already applied. Figures A.4 and A.5 provide partial listings of the original and modified versions of the subroutine CMPMAP. In CMPMAP, the compressor power and mass flow rate are calculated. Program lines that appear in bold in the modified version (Figure A.5) designate the changes that were made. Each listing contains the program line calling on subroutine SUPCOR to adjust compressor power and mass flow rate from map to actual operating conditions. For definitions of the variables that appear in the listings provided in Figures A.4 and A.5, refer to the first reference cited in the introduction to this Appendix.

Figure A.4 Subroutine CMPMAP: Partial Listing of Original Version

```

C***  CORRECT FOR ACTUAL SUPERHEAT LEVEL
C
      POWPXM = POWB/XMRB
      POWCOR = 1.0
      XMRCOR = 1.0
      IF(SUPERB.EQ.SUPER) GO TO 75
      CALL SUPCOR(SUCFAC,VOLFAC,TOLH,TOLS, TSICMP,TSOCMP,HINCMP,
&      SUPERB,POWPXM,POWCOR,XMRCOR)
75  CONTINUE
      POW = POWB*POWCOR*SIZFAC
      XMR = XMRB*XMRCOR*SIZFAC
      IF (CANFAC .LE. 0.0) GO TO 80
      IF (CANFAC .LE. 1.0) QCAN = CANFAC*POW
80  CONTINUE

```

Figure A.5 Subroutine CMPMAP: Partial Listing of Modified Version

```

C***  CORRECT FOR ACTUAL SUPERHEAT LEVEL
C
      POWPXM = POWB/XMRB
      POWCOR = 1.0
      XMRCOR = 1.0
      IF(SUPERB.EQ.SUPER) GO TO 75
      CALL SUPCOR(TACCM,PACCM,TOLH,TOLS, TSICMP,TSOCMP,
&                TRICMP, SUPERB, POWPXM,POWCOR,XMRCOR)
75    CONTINUE
      POW = POWB*POWCOR*SIZFAC*COMPOWCF
      XMR = XMRB*XMRCOR*SIZFAC*XMSFLOCF
      IF (CANFAC .LE. 0.0) GO TO 80
      IF (CANFAC .LE. 1.0) QCAN = CANFAC*POW
80    CONTINUE

```

Condensate Spray Routine

The condensate spray routine is called by the condenser (heat exchanger) model to determine the effects of condensate spray on the performance of the condenser. Heat transfer correlations developed by Tree *et al.* are used by the condensate spray routine to quantify the effects of the condensate spray on the condenser coil (26). The primary correlation consists of a heat-transfer coefficient for the wet coil as a function of the heat-transfer coefficient for the dry coil.

$$h_{wet} / h = 1 + [m_{eff} * h_{fg} * D] / [c_p * dT * (\mu * A * Re)] \quad (A.5)$$

Where h is the dry coil heat-transfer coefficient, h_{wet} is the wet coil heat-transfer coefficient, m_{eff} is the effective mass flow rate of condensate, h_{fg} is the enthalpy of vaporization of water, D is the hydraulic diameter, c_p is the specific heat of air, dT is the temperature difference across the condenser coil, μ is the viscosity, A is the area of the condenser coil, and Re is the Reynold's number.

Changes made to the original condensate spray routine consisted of the following: (1) ensuring that the condensate spray rate was equated to the condensation rate off the evaporator, (2) the addition of a correction factor to adjust the effect that the condensate spray has on the condenser air-side heat-transfer coefficient, and (3) the addition of a "check" on the condenser exiting air temperature to ensure that the condensate spray routine used the same exiting air temperature as the condenser (heat exchanger) model.

A listing of the condensate spray routine is provided in Figure A.6. The condensate spray rate is a function of the number of evaporator parallel circuits (NSECTE) and the condensation rate off the evaporator per circuit (XMM). The product of these two variables is the total condensation rate off the evaporator. The condensate spray rate (SPRYRT) is set equal to the total condensation rate (first program line that appears in bold print in Figure A.6).

The correction factor that has been added to the condensate spray routine is used to adjust the effect that the condensate spray has on the condenser air-side heat-transfer coefficient (the second line that appears in bold print in Figure A.6). The correction factor is input through the DATAIN subroutine and given the variable name CONDCORR. Variable TEMP1 is the variable that quantifies the effect of the condensate spray and is a function of many variables including PERC. (The equation used to calculate TEMP1 is the same as Eq. A.5 but in a different form.) PERC is the effective percentage of condensate spray evaporation that is useful to the condenser. Since the effect of the condensate spray on the air-side heat-transfer coefficient is uncertain, CONDCORR has been added to increase or decrease its effect for calibration purposes.

Figure A.6 Subroutine SPRAY: Modified Version

```

SUBROUTINE SPRAY (HAC,GA,XMUA,DEA,DELTAIR,NT,WT,XMA,FINTYP)
C
REAL NTE,NSECTE
C
COMMON /SPR/ SPRFLG,SPRYRT,PERC,CONDCORR
C
COMMON / CONDSR / TAIIC,TIC,TSATCI,HIC,PIC,XIC
&
    TAOC,TROC,TSATCO,HOC,POC,XOC
C
COMMON / PRNT5 / WAIRI, HAIR1, HAIRO, WAIRO, TACI, TWALLO,
&
    HWALLO,WWALLO,XMM, QMTPL, QSTPT, STRTP, STRTOT,
&
    TWB, RHI, TWBO, RHO, WOUT, XNTUSU,XNTTPE,
&
    EXFRE, ETPE, CSUPER,TAOSPE, TAOTPE,XMASP, XMATP
C
COMMON / EVAPOR / DEAE, DERE, DELTAE, FPE, XKFE, XKTE, AAFE,
&
    NTE, NSECTE, HCONTE, STE, WTE, SIGAE, PE, ARFTE,
&
    ARHTE, ALFARE, ALFAAE, FARE,CARE, QAE, RTBEVP, DZE,
&
    FANEFE, RHIE, FINTYE, MUNITE,FINFXE, DWHTLOSS, RECIRCLS
C
COMMON / CONDEN / DEAC,DERC,DELTAC,FPC,XKFC,XKTC,AAFC,NTC,NSECTC,
&
    HCONTC,STC,WTC,SIGAC,PC,ARFTC,ARHTC,ALFARC, ALFAAC,FARC,
&
    CARC,QAC,RTBCND,DZC,FANEFC,RHIC, FINTYC,MUNITC,FINFXC
C
CPA = 0.24
SPRYRT=XMM*NSECTE
C
AIR DENSITY IS CALCULATED BASED ON 1 ATM PRESSURE.
C
TEMP1 IS THE ENHANCEMENT FACTOR DUE TO WATER SPRAY. IT IS
C
NON-DIMENSIONAL. THE VARIABLES INCLUDED IN THE EQUATION BELOW:
C
    1050.0 = ENTHALPY OF VAPORIZATION (BTU/LB)
C
    SPRYRT = SPRAY RATE (LB/HR)
C
    PERC = EFFECTIVE PERCENTAGE OF EVAPORATION THAT IS
C
        USEFUL TO THE CONDENSER
C
    DELTAIR = OUTLET - INLET AIR TEMPERATURE DIFFERENCE
C
        IN CONDENSER (F)
C
    XMA = AIR MASS FLOW RATE (LB/HR)
C
    CPA = SPECIFIC HEAT OF AIR (BTU/(LB-F))
C
TEMP1=1050.0*SPRYRT*PERC*CONDCORR/(DELTAIR*XMA*CPA)
HAC = HAC*(1.0 + TEMP1)
RETURN
END

```


The "check" on the condenser-exiting air temperature is to ensure that the same temperature difference between the exiting and entering air temperatures across the condenser coil is used by both the condensate spray subroutine and the subroutine EXCH. EXCH is used to determine the heat transfer and resulting temperatures in one representative parallel circuit in the condenser, given all of the necessary inlet conditions, pressure drops, properties, and heat-transfer areas and coefficients. Figure A.7 provides a partial listing of the subroutine COND. Program lines that appear in bold designate the additions that were made. For definitions of the variables that appear in the listings provided in Figures A.7, refer to the first reference cited in the introduction to this Appendix.

Figure A.7 Subroutine COND: Partial Listing to Show "Check" on Exit Air Temperature

```

C      DETERMINE AIR SIDE HEAT TRANSFER COEFFICIENT 'HAC'(BTU/H-SQ FT-F)
C
      CALL HAIR(FINTYC,CPM,PRA,XMUA,DEAC,DELTAC,FPC,STC,WTC,NTC,
&              GA,ATAMIN,HAC,finfxc,XMAC,AAFC)
C
      DELTAIRC=TAOC-TAIC
      IF(DELTARC.LT.10) DELTAIRC=10.0
924    IF(SPRFLG.EQ.1)
&    CALL SPRAY(HAC,GA,XMUA,DEAC,DELTAIRC,NTC,WTC,XMA,FINTYC)
      DELCHK1 = DELTAIRC
C
C      DETERMINE OVERALL SURFACE EFFICIENCY 'SEFFXC'
C
      CALL SEFF(XKFC,DELTAC,STC,WTC,DEAC,FARC,HAC,SEFFXC)
C
C      CHECK FOR INCONSISTENT ENTERING AIR TEMPERATURE
C
      IERR = 0
      IF(TSAVG.GT.TAIC) GO TO 325
      IERR = 1
      GO TO 900
325    CONTINUE
C
C      USE SUBROUTINE EXCH TO DETERMINE CONDENSER HEAT TRANSFER
C      PERFORMANCE AND RETURN ALL RESULTS THROUGH COMMON
C
      CALL EXCH(AOM,TSTTPI,TSTTPO,HFG,HFGO,TAIC,XMR,
&              RTUBES,RCNCON,XNTU)
      DELCHK2 = TAOC-TAIC
      DELDIFF = ABS(DELCHK1-DELCHK2)
      IF(DELDIFF.LE.0.4) GO TO 923
      DELTAIRC = DELCHK2
      GO TO 924
923    CONTINUE

```

Air-Side Heat-Transfer Coefficients

The air-side heat-transfer coefficients for both the evaporator and condenser are computed by the subroutine HAIR. The simulation model assumes that the air-side heat-transfer coefficients for wavy and louvered fins can be predicted approximately by the use of an equation for smooth fins increased by a multiplicative constant (i.e., an enhancement factor). The heat-transfer coefficients determined for wavy and louvered fin surfaces are assumed to be referenced to smooth-fin surface areas; thus the multiplicative constants for wavy and louvered fins are intended to account for increases in both the heat-transfer coefficient and surface area from smooth fin values.

At the time the simulation model was first developed, data were not available to verify whether an equation for smooth fins could be used to predict the air-side heat-transfer coefficients for wavy and louvered fins. Since that time, research has been conducted to determine the performance of fin-and-tube heat exchangers incorporating wavy and enhanced/louvered fins (27) (28). Out of this research, correlations have been developed to predict the air-side heat-transfer coefficients and friction factors of heat exchangers using wavy and louvered fins. The fin-and-tube heat exchangers used in this research were of the type generally found in central air conditioners. Because of this, the limitations on the fin enhancement correlations are usually exceeded when they are applied to room air conditioners. Thus, manufacturers' data were relied upon to make estimates of the enhancement factor that should be used for predicting the air-side heat-transfer coefficients of wavy and louvered fins. Though manufacturers' data were used, the correlations were not abandoned entirely as they served as a check to determine if the manufacturers' estimates were reasonable.

As mentioned previously, subroutine HAIR of the simulation model is used to calculate the air-side heat-transfer coefficients of smooth, wavy, and louvered/enhanced fin surfaces. As mentioned above, the simulation model assumes that the air-side heat-transfer coefficients for wavy and louvered fins can be predicted approximately by the use of an equation for smooth fins increased by a multiplicative constant (i.e., an enhancement factor). The original version of this subroutine contains correlations to calculate the multiplicative constant (i.e., enhancement factor) for a specific type of enhanced/louvered fin surface (29). For wavy fins, the subroutine uses a constant enhancement factor of 1.45 regardless of the type of wavy fin used. The simulation model was modified so that fin enhancement factors for both the evaporator and condenser (i.e., input variable FINFXC for condensers and FINFXE for evaporators) could be input. Subroutine HAIR was modified so that the specified fin enhancement factors were used instead of the correlations (for louvered fins) and constants (for wavy fins) specified by the original routine.

Divider Wall Heat Losses

Because the simulation model was originally developed to simulate the performance of central air conditioners, no provisions were made to estimate the heat losses that are unique to room air conditioners.

The divider wall is that portion of the cabinet that separates the outdoor section of the room air conditioner from the indoor section. Divider wall heat losses are composed of two parts: heat leakage and air leakage losses. Heat leakage losses are a result of the temperature difference between the two sections of the room air conditioner. The warmer outdoor section transfers heat through the divider wall to the cooler indoor section. Manufacturers usually insulate the divider wall (typically with Styrofoam) to try to limit the heat leakage through the divider wall. Air leakage losses are a result of the outdoor air that is drawn into the indoor section through cracks and open spaces in the divider wall. The total divider wall heat loss creates an additional load on the room air conditioner and reduces its capacity and efficiency.

AHAM provided test data indicating what the divider wall heat losses are for typical room air conditioners in each of the five primary product classes. These heat losses are provided in Table A.1. The representative values listed in Table A.1 were used as input to the simulation model to model the divider wall heat losses for each of the baseline units. When analyzing prospective design options, the divider wall heat losses were assumed to remain constant. Subroutines EVAPR and SUMCAL were modified to include the effect of the divider wall heat losses on the discharge air temperature and capacity of the unit, respectively.

Table A.1 Divider Wall Heat Losses

Product Class	Capacity <i>Btu/hour</i>	Total Heat Loss <i>Btu/hour</i>
Less than 6000 Btu/h	5900	180
6000 to 8000 Btu/h	7500	180
8000 to 14,000 Btu/h	12,000	122
14,000 to 20,000 Btu/h	18,000	380
Over 20,000 Btu/h	25,000	350

Figure A.8 provides a partial listing of the modified version of subroutine EVAPR. The listing in bold print indicates the modification that was made. In order to account for the effect the divider wall heat loss has on the temperature of the exiting (discharge) air, the divider wall heat loss input variable (DWHTLOSS) is divided by the heat capacity and the mass flowrate of the exiting air and added to the average air temperature leaving the evaporator coil (TAOOE).

Figure A.8 Partial Listing of Subroutine EVAPR: Modified Version

```

C      OPTIONS FOR ADDING FAN AND/OR COMPRESSOR HEAT TO EXITING AIR
C
      TAOOE = TAOE
      IF (NCORH.EQ. 2) GO TO 725
      EINDF = QFANE
      IF (MFANIN.EQ. 2) TAOOE = TAOOE + QFANE/(CPM*XMA)
      TAOOE = TAOOE + DWHTLOSS/(CPM*XMA)
      GO TO 750

```

Figure A.9 provides a partial listing of the modified version of subroutine SUMCAL. The listing in bold print indicates the modification that was made. In order to account for the effect the heat loss has on the capacity of the unit, the divider heat loss input variable is subtracted from the calculated system capacity of the unit.

Figure A.9 Partial Listing of Subroutine SUMCAL: Modified Version

```
C      CALCULATE SYSTEM CAPACITY
C
      IF (NCORH.EQ. 2) GO TO 575
      CAPHP = QE + QSUCLN
      IF(MFANIN.EQ.2) CAPHP = CAPHP - EINDF
      CAPHP = CAPHP - DWHTLOSS
```

Suction Line Heat Gain

Because the refrigerant suction line in a room air conditioner lies within the indoor section of the unit, the heat gain absorbed by the suction line from the inlet air stream should be included as part of the total capacity of the unit. Figure A.9 contains the change that was made to the simulation model so that the suction line heat gain is included into the total capacity of the unit. This change appears in the line where the capacity (CAPHP) is set equal to the total rate of heat transfer for the evaporator (QE) plus the rate of heat gain in the suction line (QSUCLN).

Discharge Air Recirculation Heat Losses

Some portion of the air that is discharged from a room air conditioner is immediately drawn back into the unit. This short-circuiting of the evaporator discharge air decreases the capacity and the efficiency of the room air conditioner. The conditioned discharge air that is introduced into the air being drawn into the room air conditioner reduces the heat content of the inlet air stream. Because there is less heat to be extracted from the inlet air stream, the capacity of the unit is reduced. Since the energy input to the room air conditioner essentially remains the same, the efficiency of the unit is also decreased.

AHAM provided test data on an 18,000 Btu/h unit to determine the effect of recirculation on capacity and efficiency. First the unit was tested in a calorimeter room where normal short-circuiting was allowed to occur. The unit was retested in a psychrometric room where ducting was used to prevent short-circuiting. In the case of the psychrometric room test, refrigerant was added to the unit so that its superheat would be equal to what was measured in the calorimeter room test (this being the point at which the unit would be balanced if there were no short-circuiting). Table A.2 lists the results.

Table A.2 Recirculation Heat Losses

	Without Recirculation	With Recirculation	Difference
Capacity, Btu/h	18,476	17,331	-6.2%
Power, Watts	2021	2028	+0.3%
EER, Btu/Watt-hr	9.14	8.55	-6.5%

The 6% decrease in the capacity and efficiency of the tested unit was assumed to be representative of the recirculation losses that exist in all room air conditioner units. In order to simulate this 6% decrease, the inputs for the temperature and humidity of the inlet air were adjusted until a 6% decrease in the capacity and efficiency were realized. Thus, no modifications were actually made to the simulation model. Only the properties of the inlet air were modified. The DOE test procedure specifies an inlet air temperature and relative humidity of 80° F and 50%, respectively. Table A.3 lists the actual temperatures and humidities that were used for each of the baseline units to account for recirculation heat losses. When analyzing prospective design options, the modified inlet air temperatures and humidities were assumed to remain constant.

Table A.3 Inlet Air Temperatures and Humidities to Account for Recirculation Heat Losses

Product Class	Temperature °F	Relative Humidity %
Less than 6000 Btu/h	74.0	60.0
6000 to 8000 Btu/h	73.0	60.0
8000 to 14,000 Btu/h	76.0	53.0
14,000 to 20,000 Btu/h	73.0	60.0
Over 20,000 Btu/h	73.5	55.5

Air Delivery System Description

Because the simulation model was developed to model the performance of central air conditioners, the air delivery system is described with two fans (one for the condenser and one for the evaporator) that are each driven by their own fan motors. In the case of room air conditioners, the evaporator and condenser fans are both driven by a single fan motor. Because of this difference, room air conditioners are difficult to describe with the simulation model's input scheme.

No attempt was made to change the simulation model so that a room air conditioner's air delivery system could be described with one fan motor instead of two. Rather, a methodology was developed so that the simulation model's input scheme could be used to describe a room air conditioner's air delivery system.

The methodology is based upon determining what percentages of the fan motor's power are dedicated to driving the evaporator fan and condenser fan. The percentages were established based on comments from room air conditioner manufacturers. For all baseline units, the evaporator fan was assumed to draw 40% of the total fan motor power, while the condenser fan was assumed to draw the remaining 60%. For each of the baseline units modeled, manufacturers' data were provided that indicated the power draw of the fan motor. With the assumption of the "40/60 split," the power draw of the evaporator and condenser fans could easily be determined.

Specifying the fan power draw of each of the fans was suitable for modeling the baseline units, but for estimating the effect of prospective design options on the energy efficiency of a room air conditioner, the combination fan and fan motor efficiency was needed to describe the performance of each of the fans. The Oak Ridge Heat Pump Model uses the following expression to demonstrate the relationship between the fan motor power draw and the combined fan and fan motor efficiency.

$$W_{fan} = (11.1) (CFM) (dP_{air}) / \eta_{fan,motor} \quad (A.6)$$

W_{fan} is the fan motor power consumption in Btu per hour, CFM is the volumetric flow rate in cubic feet per minute, dP_{air} is the air-side pressure drop across the evaporator or condenser in pounds per square inch, $\eta_{fan,motor}$ is the combined fan and fan motor efficiency, and 11.1 is a constant that is used to convert to consistent units. Thus, the above equation can be used to calculate the combined fan and fan motor efficiency if the fan motor power consumption, the volumetric flow rate, and the pressure drop are known. As stated previously, manufacturers provided the fan motor power draw for each of the baseline units that were modeled. In addition, the volumetric air flow rates for both the evaporator and condenser were also given. With both the fan motor power draw and the volumetric air flow rates specified, the simulation model was run to generate the pressure drops across the heat exchanger coils. With the pressure drops determined, Eq. A.6 was used to solve for the combined fan and fan motor efficiency for both the evaporator and condenser fans. For each of the baseline units, Table A.4 provides a listing of the evaporator and condenser fan characteristics, including the combined fan and fan motor efficiency.

Table A.4 Evaporator and Condenser Fan and Fan Motor Characteristics

Product Class	Evaporator				Condenser			
	W_{fan}	CFM	dP_{air}	$\eta_{fan,motor}$	W_{fan}	CFM	dP_{air}	$\eta_{fan,motor}$
	watts	cfm	psi		watts	cfm	psi	
Less than 6000 Btu/h	50.0	180	0.0046	5.41%	75.0	330	0.0018	2.58%
6000 to 8000 Btu/h	55.5	210	0.0078	9.63%	83.5	380	0.0027	4.03%
8000 to 14,000 Btu/h	70.0	285	0.0072	9.52%	105.1	645	0.0049	9.76%
14,000 to 20,000 Btu/h	118.8	515	0.0120	16.90%	178.6	870	0.0064	10.14%
Over 20,000 Btu/h	149.4	534	0.0084	9.74%	224.7	1231	0.0080	14.21%

When analyzing prospective design options (excluding options that improved the fan motor efficiency), the combined fan and fan motor efficiency that was determined for each baseline unit was assumed to remain constant.

In analyzing improvements to the fan motor efficiency, the combined fan and fan motor efficiency was multiplied by the ratio of the new fan motor efficiency to the baseline fan motor efficiency. For example, in the case of the less than 6,000 Btu/h product class, the baseline shaded pole fan motor efficiency equals 30%. In analyzing the efficiency increase due to replacing the shaded pole motor with a PSC motor, the fan motor efficiency is increased to 50%. The new combined fan and fan motor efficiency is determined by multiplying the baseline combined fan and fan motor efficiency (5.41% for the evaporator fan and 2.58% for the condenser fan) by the ratio of 50%-to-30%. This yields a combined fan and fan motor efficiency of 9.02% for the evaporator fan and 4.30% for the condenser fan.

Entering Air Streams Evaluated as Moist Air

For both the evaporator and condenser, the simulation model evaluates the density and, in turn, the mass flow rate of the entering air stream at dry conditions (i.e., 0% relative humidity) rather than at the actual humidity that the entering air has been specified at. The following equation is used by the simulation model to determine the density of the entering air stream.

$$\rho = (R * T / p) \quad (A.7)$$

where ρ is the density of the moist air, R is the universal gas constant, T is the temperature of the moist air, and p is the pressure of the moist air. The above equation essentially obeys the perfect gas equation of state. In order to account for the humidity of the entering air stream, the following equation, provided by the *1989 ASHRAE Fundamentals Handbook*, was used.

$$\rho = (R * T / p) (1 + 1.6078 W) \quad (A.8)$$

where W is the moist air's humidity ratio. In the simulation model, subroutines EVAPR (for the evaporator) and COND (for the condenser) contain the expressions for calculating the density and mass flow rate of the entering air stream. In the subroutines, the expression for calculating the density of the entering air stream was changed to include the effects of the moisture content of the air (i.e., Eq. A.8).

A.1.3 Input Data Modifications

The modifications made to the Oak Ridge Heat Pump Design Model have required that changes be made to the input data. Most of the changes have consisted of adding additional input variables. These new input variables are necessary for modeling the affects that are unique to room air conditioners. Some of the new input variables were a result of the original modifications that were made to the Heat Pump Design Model in order to simulate the

performance of room air conditioners (30). The remainder of the new input variables were added as a result of the additional revisions necessary for modeling the affects described in this Appendix.

A description of the input data is provided below. Most of the input data can be described by referring to the original Mark III program documentation (Appendix A) (31). When the original documentation can be used, the number of the appropriate card that contains the description is given. All new input variables are fully described. An annotated listing of a sample input data file is provided in Figure A.10.

Input Data Descriptions

Input Line 1

Same as Card #1 in Mark III Program Documentation, Appendix A.

Input Line 2

Same as Card #2 in Mark III Program Documentation, Appendix A.

Input Line 3

Same as Card #3 in Mark III Program Documentation, Appendix A.

Input Line 4

ICAPFLAG Switch for specifying the capacity of the room air conditioner.

= 0, system capacity is not specified.

= 1, system capacity is specified by input variable CAPACITY.

CAPACITY if ICAPFLAG = 1, the simulation model will vary the displacement of the compressor until the system capacity equals the value of CAPACITY (Btu/h).

EPSILON if ICAPFLAG = 1, the value of EPSILON specifies the tolerance on CAPACITY for which the simulation model will stop iterating (Btu/h).

Input Line 5

Same as Card #4 in Mark III Program Documentation, Appendix A.

Input Line 6

No Subcooler

ISUB = 0, no subcooler present.

Tube-in-Condensate Subcooler

ISUB = 1, for the tube-in-condensate subcooler.

INDIA The inner diameter of the refrigerant tube (inches).

OUTDIA The outer diameter of the refrigerant tube (inches).

LENGTH The length of the subcooler refrigerant tube (inches).

TCOND The temperature of the condensate pool (°F).

Tube-in-Tube Subcooler

ISUB = 2, for the tube-in-tube subcooler.

INDIA The diameter of the inner tube (inches).

OUTDIA The diameter of the outer tube (inches).

LENGTH The length of the subcooler (inches).

RIDGE Ridge height on inside tube outer surface (inches).

Input Line 7

Modification of an existing input line for specifying the type of flow control device. Input data descriptions for specifying fixed condenser subcooling, a thermostatic expansion valve, and a short tube orifice are the same as Card #5 in Mark III Program Documentation, Appendix A. For specifying a capillary tube the following input data description are used.

IREFC = 2, or a capillary tube expansion device.

CAPLEN The capillary tube length (inches).

CAPDIA The capillary tube diameter (inches).

NCAP The number of capillary tubes in parallel.

Input Line 8

Modification of an existing input line. The input data descriptions for the first two input variables on this input line (TSICMP and TSOCMP) are the same as Card #6 in Mark III Program Documentation, Appendix A. The third and fourth input variables on the input line are used when an accumulator is present. The fifth and sixth input variables on the input line are used to adjust the calculated compressor power and refrigerant mass flow rate.

TACCM The temperature increase across the accumulator (°F).

PACCM The pressure drop across the accumulator (psi).

COMPOWCF Correction factor for adjusting the compressor power. Values less than one decrease the calculated compressor power. Values greater than one increase the calculated compressor power.

XMSFLOCF Correction factor for adjusting the refrigerant mass flow rate. Values less than one decrease the calculated mass flow rate. Values greater than one increase the calculated mass flow rate.

Input Line 9

Same as Card #7 in Mark III Program Documentation, Appendix A.

Input Line 10

Same as Card #8 in Mark III Program Documentation, Appendix A.

Input Line 11

Same as Card #9 in Mark III Program Documentation, Appendix A.

Input Line 12

ERTFLG Switch for specifying grooved (rifled) refrigerant tubing in the evaporator.
= 0, specify smooth tubing.

= 1, specify grooved tubing.

ERTMULT Multiplier for the increase in the refrigerant-side heat transfer coefficient due to the grooved tubing. The value is relative to the heat transfer coefficient for smooth tubing.

Input Line 13

Same as Card #10 in Mark III Program Documentation, Appendix A, with the exception that an additional input variable has been added to the end of the input line to specify the heat losses associated with the divider wall.

DWHTLOSS The heat loss associated with the divider wall. This represents the heat loss due to both heat transfer and air leakage (Btu/h).

Input Line 14

Same as Card #11 in Mark III Program Documentation, Appendix A. (Input variables DDUCT and FIXCAP have no effect on the simulation model.)

Input Line 15

Same as Card #12 in Mark III Program Documentation, Appendix A, with the exception that an additional input variable has been added to the end of the input line to specify the effects of different fin types on the performance of the evaporator.

FINFXE Multiplier for the increase in the air-side heat-transfer coefficient due to high performance fins (i.e., wavy, louvered, enhanced (slit)). The value is relative to the heat-transfer coefficient for flat fins.

Input Line 16

Same as Card #13 in Mark III Program Documentation, Appendix A.

Input Line 17

CRTFLG Switch for specifying grooved (rifled) refrigerant tubing in the condenser.
= 0, specify smooth tubing.
= 1, specify grooved tubing.

CRTMULT Multiplier for the increase in the refrigerant-side heat transfer coefficient due to the grooved tubing. The value is relative to the heat transfer coefficient for smooth tubing.

Input Line 18

SPRFLG Switch for specifying whether condensate is sprayed on to the condenser.
= 0, specifies that no condensate is sprayed.
= 1, specifies that condensate spray is utilized.

PERC Effective percentage of condensate spray evaporation that is useful to the condenser.

CONDCORR Correction factor for adjusting the effect that the condensate spray has on the condenser's air-side heat-transfer coefficient. Values less than one decrease the heat transfer coefficient. Values greater than one increase the heat transfer coefficient.

Input Line 19

Same as Card #14 in Mark III Program Documentation, Appendix A.

Input Line 20

Same as Card #15 in Mark III Program Documentation, Appendix A.

Input Line 21

Same as Card #16 in Mark III Program Documentation, Appendix A with the exception that an additional input variable has been added to the end of the input line to specify the effects of different fin types on the performance of the condenser.

FINFXC Multiplier for the increase in the air-side heat transfer coefficient due to high performance fins (i.e., wavy, louvered, enhanced (slit)). The value is relative to the heat transfer coefficient for flat fins.

Input Line 22

Same as Card #17 in Mark III Program Documentation, Appendix A.

Input Line 23

Same as Card #18 in Mark III Program Documentation, Appendix A.

Input Line 24

Same as Card #19 in Mark III Program Documentation, Appendix A.

Input Line 25

DLL	Inside diameter of the liquid line (inches).
XLEQLL	Equivalent length of the liquid line (feet).
DSL	Inside diameter of the suction line (inches).
XLEQSL	Equivalent length of the suction line (feet).
DDL	Inside diameter of the discharge line (inches).
XLEQDL	Equivalent length of the discharge line (feet).

Figure A.10 Annotated Listing of a Sample Input Data File

ITITLE

COMPANY Q, LESS THAN 6000 BTUH

LPRINT

1

NCORH

1

ICAPFLAG CAPACITY EPSILON
0 5950.00 3.0

ICHRGE SUPER
0 16.0

ISUB INDIA OUTDIA LENGTH TCOND
1 0.2880 0.3125 17.3 85.00

IREFC CAPLEN CAPDIA NCAP
2 42.50 0.0460 1.0

TSICMP TSOCMP TACCM PACCM COMPOWCF XMSFLOCF
40.50 132.00 5.00 1.00 0.988 1.00

ICOMP DISPL SYNC QCAN CANFAC
2 0.580 3450.00 749.0 0.00

CPOW(1) CPOW(2) CPOW(3) CPOW(4) CPOW(5) CPOW(6) DISPLB SUPERB
1.667E-05 -6.933E-04 -8.750E-05 9.500E-04 6.500E-05 1.818E-01 0.580E+00 -9.500E+01

CXMR(1) CXMR(2) CXMR(3) CXMR(4) CXMR(5) CXMR(6)
-4.367E-03 1.163E+00 1.263E-02 1.542E+00 -6.430E-03 -4.392E+01

ERTFLG ERTMULT
0 2.500

TAIH RHI DWHTLOSS
74.0 0.600 180.0

QAI FANEFI DDUCT FIXCAP
180.0 0.0541 8.00 19000.0

AAFI NTI NSECTI WTI STI RTBI FINFXE
0.8700 2.0 1.0 0.625 1.0 19.0 1.690

FINTYI FPMI DELTAI DEAI DERI XKFI XKTI HCONTI
2.0 14.0 0.0060 0.3750 0.3510 128.3 225.0 100.0

CRTFLG CRTMULT
0 2.000

SPRFLG PERC CONDCORR
1 0.95 1.00

TAHO RHO
95.0 0.400

QAO 330.0	FANEFO 0.0258	MFANFT 0					
AAFO 1.6000	NT0 2.0	NSECT0 1.0	WTO 0.625	STO 1.0	RTBO 27.0	FINFXC 1.660	
FINTYO 2.0	FPO 18.0	DELTAO 0.0050	DEAO 0.3125	DERO 0.2880	XKFO 128.3	XKTO 225.0	HCONTO 100.0
MCMPOP 1	MFANIN 0	MFANOU 1					
QSUCLN 000.0	QDISLN 100.0	QLIQLN 100.0					
DLL 0.2880	XLEQLL 00.007	DSL 0.3190	XLEQSL 3.333	DDL 0.1940	XLEQDL 3.00		

Baseline Unit Descriptions

Figures A.11 through A.15 provide listings of the input data files for each of the baseline units that were modeled. As described in Chapter 1 of this volume, the input data description for the five primary product classes (i.e., classes without reverse cycle and with louvered sides) served as input data for the other seven non-primary product classes (i.e., those either with reverse cycle or without louvered sides). For non-primary classes without reverse cycle, the capacity of the non-primary class dictated which primary product class was used to describe it. For example, in the case of the non-primary class without louvered sides and where the capacity is less than 6,000 Btu/h, the input data to describe its baseline characteristics were taken from the primary class with the same capacity (i.e., less than 6,000 Btu/h). For non-primary product classes with reverse cycle, the input data for the primary class with capacity between 14,000 and 20,000 Btu/h was used to describe the class with louvered sides. The input data for the primary class with capacity between 8,000 and 14,000 Btu/h was used to describe the class without louvered sides.

Figure A.11 Baseline Input Data Description - Room Air Conditioners Without Reverse Cycle and With Louvered Sides, Less Than 6,000 Btu/h

COMPANY Q, LESS THAN 6000 BTUH

1							
1							
0	5950.00	3.0					
0	16.0						
1	0.2880	0.3125	17.3	85.00			
2	42.50	0.0460	1.0				
40.50	132.00	5.00	1.00	0.988	1.00		
2	0.580	3450.00	749.0	0.00			
1.667E-05	-6.933E-04	-8.750E-05	9.500E-04	6.500E-05	1.818E-01	0.580E+00	-9.500e+01
-4.367E-03	1.163E+00	1.263E-02	1.542E+00	-6.430E-03	-4.392E+01		
0	2.500						
74.0	0.600	180.0					
180.0	0.0541	8.00	19000.0				
0.8700	2.0	1.0	0.625	1.0	19.0	1.690	
2.0	14.0	0.0060	0.3750	0.3510	128.3	225.0	100.0
0	2.000						
1	0.95	1.00					
95.0	0.400						
330.0	0.0258	0					
1.6000	2.0	1.0	0.625	1.0	27.0	1.660	
2.0	18.0	0.0050	0.3125	0.2880	128.3	225.0	100.0
1	0	1					
000.0	100.0	100.0					
0.2880	00.007	0.3190	3.333	0.1940	3.00		

Figure A.12 Baseline Input Data Description - Room Air Conditioners Without Reverse Cycle and With Louvered Sides, 6,000 to 7,999 Btu/h

COMPANY R, 6000 TO 7999 BTUH

1								
1								
0	7550.00	3.0						
0	3.4							
1	0.2880	0.3125	34.5	85.00				
2	45.00	0.0523	1.0					
40.50	132.00	5.00	1.0	1.101	0.990			
2	0.700	3450.00	643.0	0.00				
1.813E-05	2.758E-04	-1.250E-05	-4.225E-04	3.580E-05	2.327E-01	0.700E+00	2.00E+01	
-2.689E-04	-7.688E-02	1.197E-02	1.153E+00	-4.067E-04	5.980E+01			
0	2.500							
73.0	0.600	180.0						
210.0	0.0963	8.00	19000.0					
0.8700	3.0	1.0	0.625	1.0	29.0	1.480		
2.0	14.0	0.0060	0.3750	0.3510	128.3	225.0	100.0	
0	2.000							
1	0.95	1.0						
95.0	0.400							
380.0	0.0403	0						
1.6000	3.0	1.0	0.625	1.0	41.0	1.490		
2.0	16.0	0.0050	0.3125	0.2880	128.3	225.0	100.0	
1	0	1						
000.0	100.0	100.0						
0.2880	0.007	0.3190	3.333	0.3750	3.000			

Figure A.13 Baseline Input Data Description - Room Air Conditioners Without Reverse Cycle and With Louvered Sides, 8,000 to 13,999 Btu/h

COMPANY Z, 8000 TO 13,999 BTUH

1								
1								
0	12000.00	3.0						
0	9.0							
1	0.2885	0.3125	37.2	85.00				
2	33.00	0.0468	2.0					
40.5	132.00	5.00	1.0	1.011	1.100			
2	1.120	3450.00	907.5	0.00				
4.629E-05	-5.150E-03	-1.732E-04	2.889E-03	1.279E-04	6.024E-01	1.120E+00	-9.500e+01	
-7.798E-03	1.510E+00	1.324E-02	2.516E+00	-5.159E-04	-2.649E+01			
0	2.500							
76.0	0.530	122.0						
285.0	0.0952	8.00	19000.0					
1.0600	3.0	1.83	0.625	1.0	29.0	1.920		
3.0	14.0	0.0045	0.3125	0.2885	128.3	225.0	100.0	
0	2.000							
1	0.95	1.0						
95.0	0.400							
645.0	0.0976	0						
1.7200	3.0	1.0	0.625	1.0	41.0	1.950		
3.0	14.0	0.0045	0.3125	0.2885	128.3	225.0	100.0	
1	0	1						
000.0	100.0	100.0						
0.3125	0.500	0.5000	4.000	0.6250	3.167			

Figure A.14 Baseline Input Data Description - Room Air Conditioners Without Reverse Cycle and With Louvered Sides, 14,000 to 19,999 Btu/h

COMPANY J, 14,000 TO 19,999 BTUH

1								
1								
0	17900.00	3.0						
0	9.6							
1	0.3640	0.3920	45.8	85.00				
2	38.00	0.0735	1.0					
40.50	132.00	5.00	1.0	0.991	1.005			
2	1.540	3450.00	1449.0	0.00				
8.231E-05	-1.327E-02	-1.889E-04	6.276E-03	1.058E-04	1.601E+00	1.540E+00	-9.500e+01	
-5.827E-03	6.254E-01	3.569E-02	1.799E+00	4.034E-03	7.686E+01			
1	3.510							
73.0	0.600	380.0						
515.0	0.1690	8.00	19000.0					
1.5600	3.0	3.0	0.866	1.0	33.0	1.880		
3.0	13.0	0.0045	0.3920	0.3640	128.3	225.0	100.0	
0	2.580							
1	0.95	1.0						
95.0	0.400							
870.0	0.1014	0						
2.4200	3.0	1.63	0.866	1.0	46.0	1.890		
3.0	15.0	0.0045	0.3920	0.3640	128.3	225.0	100.0	
1	0	1						
000.0	100.0	100.0						
0.3190	1.000	0.4440	4.167	0.3190	3.000			

Figure A.15 Baseline Input Data Description - Room Air Conditioners Without Reverse Cycle and With Louvered Sides, Greater than 20,000 Btu/h

COMPANY K, GREATER THAN 20,000 BTUH

1								
1								
0	24200.00	3.0						
0	18.0							
1	0.3640	0.3920	45.8	85.00				
2	40.00	0.0855	1.00					
40.50	132.00	5.00	1.00	1.007	0.883			
2	2.180	3450.00	2640.0	0.00				
-2.058E-04	8.303E-02	-1.575E-04	2.950E-02	-7.937E-05	-5.076E+00	2.180E+00	-9.500E+01	
1.364E-02	-3.792E+00	5.871E-02	4.437E+00	-1.257E-02	4.188E+02			
1	4.130							
73.5	0.555	350.0						
534.0	0.0974	8.00	19000.0					
2.0400	3.0	3.0	0.866	1.0	33.0	1.850		
3.0	14.0	0.0045	0.3920	0.3640	128.3	225.0	100.0	
1	2.320							
1	0.95	1.0						
95	0.400							
1231.0	0.1421	0						
2.7200	3.0	1.64	0.866	1.0	52.0	1.920		
3.0	12.0	0.0045	0.3920	0.3640	128.3	225.0	100.0	
1	0	1						
000.0	100.0	100.0						
0.3190	1.000	0.5550	5.000	0.3190	3.833			

A.1.4 Map-Based Compressor Model Input Data

As mentioned previously in this appendix, the compressor model used in the analysis of room air conditioners is a map-based model. The map-based compressor model uses empirical performance curves obtained from compressor calorimeter measurements performed by compressor manufacturers. These performance curves provide compressor motor power input, refrigerant mass flow rate, and/or refrigerating capacity as functions of "evaporator" saturation temperature (i.e., at the compressor shell inlet) for four to six "condenser" saturation temperatures (i.e., at the the compressor shell outlet).

The Oak Ridge Heat Pump Design Model also provides a second type of compressor model; a loss and efficiency model. This model uses a more general routine than the map-based model, which attempts to model the internal energy balances in a reciprocating compressor using user-supplied heat loss and internal efficiency values. Because the loss and efficiency model cannot predict compressor performance as accurately over the same range of operating conditions as the map-based model, the map-based model was selected and used to model the compressor.

The routine in the map-based compressor model uses curve fits to the compressor motor power input (watts) and the refrigerant mass flow rate (lbm/hr) as functions of compressor shell inlet and outlet saturation temperatures to model the published performance data. The user must provide sets of coefficients for bi-quadratic functions of the form given by Eq. A.9 for the power input and mass flow rate as functions of the inlet and outlet saturation temperatures.

$$(T_{\text{outlet}} \quad T_{\text{inlet}}) = C_1 T_{\text{outlet}}^2 + C_2 T_{\text{outlet}} + C_3 T_{\text{inlet}}^2 + C_4 T_{\text{inlet}} + C_5 T_{\text{outlet}} T_{\text{inlet}} + C_6 \quad (\text{A.9})$$

These coefficients are input on line numbers 8 and 9 of the input data (refer to input data description). A short computer program that uses a least squares algorithm to compute these coefficients is provided with the Oak Ridge Heat Pump Design Model. There are two versions of this computer program. One version is used with compressor map data that are based on a return gas temperature of 95° F. The other version is used with map data based on a superheat temperature of 20° F.

A description of the input data for the computer program is provided below. An annotated listing of a sample input data file is provided in Figure A.16.

Input Data Description for Map-Based Compressor Computer Program

Input Line 1a

ANSI

= POWR, designates that the following data pertains to the compressor motor input.

Input Line 2a

TITLE

Descriptive title for the compressor described by this set of data.

Input Line 3a

Variables that designate the number of compressor map points that will be used to determine the coefficients for the bi-quadratic function for compressor motor power.

XNX Specifies the number of condenser saturation temperatures.
XNY Specifies the number of evaporator saturation temperatures.

Input Line 4a

SUPER1 Depending on the version of the computer program that is being used, this variable specifies the return gas temperature or the amount of superheat. If the compressor map data is based on a return gas temperature, enter the negative of the value (e.g. -95° F). If the compressor map data is based on a value of superheat, enter the superheat value (e.g. 20° F).

SUBCOL1 Specifies the amount of subcooling the compressor map data is based upon (°F).

DISPL1 Specifies the compressor displacement that the compressor map data is based upon (cubic inches).

RPM1 Specifies the rpm of the compressor that the compressor map data is based upon (rpm).

Input Line 5a

TSATC1(XNX) Specifies the condenser saturation temperatures that will be used to determine the coefficients for the bi-quadratic function for the compressor motor power (°F). The number of temperatures provided on this Input Line must equal the number specified by the input variable XNX. For example, if four temperatures are entered on this Input Line, XNX equals four.

Input Line 6a

TSATE1(XNY) Specifies the evaporator saturation temperatures that will be used to determine the coefficients for the bi-quadratic function for the compressor motor power (°F). The number of temperatures provided on this Input Line must equal the number specified by the input variable XNY. For example, if three temperatures are entered on this Input Line, XNY equals three.

Input Lines for Compressor Power (The number of Input Lines used for specifying the motor input values corresponds to the number of condenser saturation temperatures entered on Input Line 5a.)

POWER(XNY,XNX) Specifies the compressor motor input values at the above specified condenser and evaporator saturation temperatures (watts). The first Input Line consists of motor input values at the evaporator saturation temperatures entered on Input Line 6a and the first condenser saturation temperature entered on Input Line 5a. The subsequent Input Lines are for the remaining condenser saturation temperatures entered on Input Line 5a.

Input Lines for Weighting the Compressor Power (The number of Input Lines for Weighting are equal to the number of Input Lines used for entering the Compressor Power data.)

WGHT1(XNY,XNX) The values entered here are the "weighting" factors for the compressor motor input data entered on the above Input Lines. In general, the values here should all be 100 (100%). This indicates that all power values should be given equal weight when calculating the coefficients for the curve fitting "power" equation.

Input Line 1b

ANS1

Specifies the second type of compressor map data.
= CAPA if the following data pertains to refrigerating capacity.
= MASS if the following data pertains to mass flow rate data.

Input Line 2b

TITLE

Same data description as Input Line 2a.

Input Line 3b

XNX

Same description as XNX on Input Line 3a except data pertains to capacity or mass flow rate.

XNY

Same description as XNY on Input Line 3a except data pertains to capacity or mass flow rate.

Input Line 4b

SUPER2

Same description as SUPER1 on Input Line 4a.

SUBCL2

Same description as SUBCL1 on Input Line 4a.

DISPL2

Same description as DISPL1 on Input Line 4a.

RPM2

Same description as RPM1 on Input Line 4a.

Input Line 5b

TSATC2(XNX)

Same description as TSATC1 on Input Line 5a except data pertains to capacity or mass flow rate.

Input Line 6b

TSATE2(XNY) Same description as TSATE1 on Input Line 6a except data pertains to capacity or mass flow rate.

Input Lines for Capacity or Mass Flow Rate (The number of Input Lines used for specifying the capacity or mass flow rate corresponds to the number of condenser saturation temperatures entered on Input Line 5b.)

XMR(XNY,XNX) Same descriptions as Input Lines for Compressor Power except that the data pertains to capacity (kBtu/h) or mass flow rate (lbm/hr).

Input Lines for Weighting the Capacity or Mass Flow Rate (The number of Input Lines for Weighting are equal to the number of Input Lines used for entering the Capacity or Mass Flow Rate data.)

WGHT1(XNY,XNX) The values entered here are the "weighting" factors for the capacity or mass flow rate data entered on the above Input Lines. In general, the values here should all be 100 (100%). This indicates that all capacity or mass flow rate values should be given equal weight when calculating the coefficients for the curve fitting "mass flow rate" equation.

Figure A.16 **Annotated Listing of a Sample Input Data File for Map-Based Compressor Computer Program**

**ANS1
POWR**

TITLE

COMPANY Q

**XNX XNY
4.00 3.00**

SUPER1	SUBCL1	DISPL1	RPM1
-95.00	15.00	0.58	3450.0

TSATC1(1)	TSATC1(2)	TSATC1(3)	TSATC1(4)
110.00	120.00	130.00	140.00

TSATE1(1)	TSATE1(2)	TSATE1(3)
34.00	44.00	54.00

POWER(1,1)	POWER(2,1)	POWER(3,1)
480.0	490.0	490.0

POWER(1,2)	POWER(2,2)	POWER(3,2)
540.0	560.0	560.0

POWER(1,3)	POWER(2,3)	POWER(3,3)
590.0	610.0	620.0

POWER(1,4)	POWER(2,4)	POWER(3,4)
650.0	690.0	700.0

WGHT1(1,1)	WGHT1(2,1)	WGHT1(3,1)
100.0	100.0	100.0

WGHT1(1,2)	WGHT1(2,2)	WGHT1(3,2)
100.0	100.0	100.0

WGHT1(1,3)	WGHT1(2,3)	WGHT1(3,3)
100.0	100.0	100.0

WGHT1(1,4)	WGHT1(2,4)	WGHT1(3,4)
100.0	100.0	100.0

ANS1

CAPA

TITLE

COMPANY Q

XNX	XNY		
4.00	3.00		
SUPER2	SUBCL2	DISPL2	RPM2
-95.00	15.00	0.58	3450.0
TSATC2(1)	TSATC2(2)	TSATC2(3)	TSATC2(4)
110.00	120.00	130.00	140.00
TSATE2(1)	TSATE2(2)	TSATE2(3)	
34.00	44.00	54.00	
XMR(1,1)	XMR(2,1)	XMR(3,1)	
6.000	7.400	8.900	
XMR(1,2)	XMR(2,2)	XMR(3,2)	
5.650	7.000	8.450	
XMR(1,3)	XMR(2,3)	XMR(3,3)	
5.300	6.550	7.950	
XMR(1,4)	XMR(2,4)	XMR(3,4)	
5.000	6.000	7.250	
WGHT2(1,1)	WGHT2(2,1)	WGHT2(3,1)	
100.0	100.0	100.0	
WGHT2(1,2)	WGHT2(2,2)	WGHT2(3,2)	
100.0	100.0	100.0	
WGHT2(1,3)	WGHT2(2,3)	WGHT2(3,3)	
100.0	100.0	100.0	
WGHT2(1,4)	WGHT2(2,4)	WGHT2(3,4)	
100.0	100.0	100.0	

Compressor Baseline Unit Descriptions

Figures A.17 through A.21 provide listings of the compressor input data files for each of the baseline units that were modeled. As was done for the baseline input data, the compressor input data description for the five primary product classes (i.e., classes without reverse cycle and with louvered sides) served as input data for the other seven non-primary product classes (i.e., those either with reverse cycle or without louvered sides).

Figure A.17 Compressor Baseline Input Data Description - Room Air Conditioners Without Reverse Cycle and With Louvered Sides, Less Than 6,000 Btu/h

POWR				
COMPANY Q				
4.00	3.00			
-95.00	15.00	0.58		3450.0
110.00	120.00	130.00		140.00
34.00	44.00	54.00		
480.0	490.0	490.0		
540.0	560.0	560.0		
590.0	610.0	620.0		
650.0	690.0	700.0		
100.0	100.0	100.0		
100.0	100.0	100.0		
100.0	100.0	100.0		
100.0	100.0	100.0		
CAPA				
COMPANY Q				
4.00	3.00			
-95.00	15.00	0.58		3450.0
110.00	120.00	130.00		140.00
34.00	44.00	54.00		
6.000	7.400	8.900		
5.650	7.000	8.450		
5.300	6.550	7.950		
5.000	6.000	7.250		
100.0	100.0	100.0		
100.0	100.0	100.0		
100.0	100.0	100.0		
100.0	100.0	100.0		

Figure A.18 Compressor Baseline Input Data Description - Room Air Conditioners Without Reverse Cycle and With Louvered Sides, 6,000 to 7,999 Btu/h

POWR			
COMPANY R			
4.00	4.00		
20.00	15.00	0.70	3450.0
110.00	120.00	130.00	140.00
40.00	45.00	50.00	55.00
603.0	615.0	627.0	638.0
662.0	676.0	689.0	702.0
724.0	740.0	755.0	770.0
790.0	808.0	825.0	841.0
100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0
CAPA			
COMPANY R			
4.00	4.00		
20.00	15.00	0.70	3450.0
110.00	120.00	130.00	140.00
40.00	45.00	50.00	55.00
8.250	9.095	9.992	10.941
7.792	8.599	9.458	10.367
7.330	8.100	8.920	9.790
6.864	7.597	8.379	9.211
100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0

Figure A.19 | Compressor Baseline Input Data Description - Room Air Conditioners Without Reverse Cycle and With Louvered Sides, 8,000 to 13,999 Btu/h

POWR			
COMPANY Z			
4.00	3.00		
-95.00	15.00	1.12	3450.0
113.00	122.00	131.00	140.00
41.00	47.30	53.60	
1035.0	1045.0	1045.0	
1130.0	1150.0	1160.0	
1240.0	1265.0	1280.0	
1350.0	1390.0	1405.0	
100.0	100.0	100.0	
100.0	100.0	100.0	
100.0	100.0	100.0	
100.0	100.0	100.0	
CAPA			
COMPANY Z			
4.00	3.00		
-95.00	15.00	1.12	3450.0
113.00	122.00	131.00	140.00
41.00	47.30	53.60	
13.253	15.034	16.705	
12.499	14.205	15.912	
11.745	13.332	14.999	
10.912	12.34	13.967	
100.0	100.0	100.0	
100.0	100.0	100.0	
100.0	100.0	100.0	
100.0	100.0	100.0	

Figure A.20 Compressor Baseline Input Data Description - Room Air Conditioners Without Reverse Cycle and With Louvered Sides, 14,000 to 19,999 Btu/h

POWR				
COMPANY J				
	4.00	3.00		
	-95.00	15.00	1.54	3450.0
	113.00	122.00	131.00	140.00
	41.00	47.30	53.60	
	1580.0	1590.0	1585.0	
	1680.0	1700.0	1700.0	
	1780.0	1800.0	1800.0	
	1905.0	1930.0	1950.0	
	100.0	100.0	100.0	
	100.0	100.0	100.0	
	100.0	100.0	100.0	
	100.0	100.0	100.0	
CAPA				
COMPANY J				
	4.00	3.00		
	-95.00	15.00	1.54	3450.0
	113.00	122.00	131.00	140.00
	41.00	47.30	53.60	
	17.856	20.474	23.173	
	16.745	19.165	21.943	
	15.753	18.253	20.753	
	14.563	16.864	19.384	
	100.0	100.0	100.0	
	100.0	100.0	100.0	
	100.0	100.0	100.0	
	100.0	100.0	100.0	

Figure A.21 Compressor Baseline Input Data Description - Room Air Conditioners Without Reverse Cycle and With Louvered Sides, Greater Than 20,000 Btu/h

POWR			
COMPANY K			
4.00	3.00		
-95.00	15.00	2.18	3450.0
113.00	122.00	131.00	140.00
41.00	47.30	53.60	
2250.0	2300.0	2330.0	
2540.0	2585.0	2600.0	
2800.0	2815.0	2830.0	
3000.0	3030.0	3060.0	
100.0	100.0	100.0	
100.0	100.0	100.0	
100.0	100.0	100.0	
100.0	100.0	100.0	
CAPA			
COMPANY K			
4.00	3.00		
-95.00	15.00	2.18	3450.0
113.00	122.00	131.00	140.00
41.00	47.30	53.60	
30.554	34.522	38.688	
28.649	32.538	36.307	
27.181	30.554	34.323	
25.594	28.768	32.538	
100.0	100.0	100.0	
100.0	100.0	100.0	
100.0	100.0	100.0	
100.0	100.0	100.0	

A.2 MANUFACTURER COST DATA FOR ROOM AIR CONDITIONERS

The following tables show the total manufacturing costs (1990\$) for several design options for twelve product classes of room air conditioners. Total costs are divided into variable and capital costs. Variable costs consist of material costs, purchased parts, labor costs, shipping costs, and a portion of indirect costs. Capital costs consist of tooling costs and a portion of indirect costs. Indirect costs include expenses such as general and administrative costs, research and development, rent, utility costs, and certification tests and fees. Since cost data were provided in total cost only, assumptions were made regarding the total cost in order to determine what percentages were variable and what were capital costs. For improved designs requiring the addition of an improved purchased part (i.e., increased compressor or fan motor efficiency), the total cost was assumed to be all variable. For design options requiring changes to components manufactured in-house (i.e., heat exchanger improvements), 85% of the total cost was assumed to be variable and 15% capital. For designs requiring substantial tooling changes (i.e., variable speed compressors and increased coil areas), a split of 60% variable cost and 40% capital cost was assumed. Cost data for the seven non-primary product classes (i.e., without side louvers or

with a reversing valve) were taken directly from the cost data provided for the five primary classes (i.e., without reversing valve and with side louvers). The capacity size of the particular non-primary class dictated which primary class cost data were taken from. With the exception of the baseline costs, the variable, capital, and total incremental costs are always relative to the preceding design option. The incremental costs for each design option are per unit produced. The total costs at each design option, including the baseline, are cumulative. The estimated uncertainty (at a 95% confidence level) for the total costs are provided for each design option.

Table A.5 Total Manufacturing Costs for Room Air Conditioners (by Design Option)

Without Reverse Cycle and With Louvered Sides, Less Than 6000 Btu/h							
Std Level	Design No.	Design Option	Variable Cost	Capital Cost	Total Incr.	Total Cost	Uncert.
	0	Baseline	157.18	22.45	-	179.63	-
	1	0 + Evap/Cond Enhanced Fins	0.71	0.10	0.81	180.44	10%
1,2	2	1 + PSC Fan Motor	3.00	0.00	3.00	183.44	5%
	3	2 + Evap/Cond Grooved Tubes	2.41	0.34	2.75	186.19	10%
3	4	3 + Add Subcooler	3.10	0.44	3.54	189.73	10%
4	5	4 + Incr Compressor EER to 11.0	1.65	0.00	1.65	191.38	5%
	6	5 + Increase Evap/Cond Coil Area	16.05	10.70	26.75	218.13	15%
	7	6 + Variable Speed Compressor	60.00	40.00	100.00	318.13	25%
	8	7 + Brushless D.C. Fan Motor	60.00	0.00	60.00	378.13	25%
5	9	5 + Incr Compressor EER to 11.5	11.67	0.00	11.67	203.05	30%
6	10	9 + Increase Evap/Cond Coil Area	16.09	10.73	26.82	229.87	15%
	11	10 + Variable Speed Compressor	60.00	40.00	100.00	329.87	25%
7	12	11 + Brushless D.C. Fan Motor	60.00	0.00	60.00	389.87	25%

Without Reverse Cycle and With Louvered Sides, 6000 to 7999 Btu/h							
Std Level	Design No.	Design Option	Variable Cost	Capital Cost	Total Incr.	Total Cost	Uncert.
	0	Baseline	175.28	25.04	-	200.32	-
	1	0 + Evap/Cond Enhanced Fins	0.98	0.14	1.12	201.44	10%
1,2	2	1 + PSC Fan Motor	3.00	0.00	3.00	204.44	5%
	3	2 + Add Subcooler	3.10	0.44	3.54	207.98	10%
3,4	4	3 + Evap/Cond Grooved Tubes	3.61	0.52	4.13	212.11	10%
	5	4 + Increase Evap/Cond Coil Area	16.84	11.23	28.07	240.18	15%
	6	5 + Variable Speed Compressor	60.00	40.00	100.00	340.18	25%
	7	6 + Brushless D.C. Fan Motor	61.83	0.00	61.83	402.01	25%
5	8	4 + Incr Compressor EER to 11.5	13.56	0.00	13.56	225.67	30%
6	9	8 + Increase Evap/Cond Coil Area	17.03	11.36	28.39	254.06	15%
	10	9 + Variable Speed Compressor	60.00	40.00	100.00	354.06	25%
7	11	10 + Brushless D.C. Fan Motor	61.83	0.00	61.83	415.89	25%

Table A.5 Total Manufacturing Costs for Room Air Conditioners (by Design Option) Cont'd**Without Reverse Cycle and With Louvered Sides, 8000 to 13,999 Btu/h**

Std Level	Design No.	Design Option	Variable Cost	Capital Cost	Total Increment.	Total Cost	Uncert.
1	0	Baseline	224.32	32.04	-	256.36	-
	1	0 + Add Subcooler	1.70	0.24	1.94	258.30	10%
2	2	1 + Incr Compressor EER to 10.7	4.64	0.00	4.64	262.94	5%
3,4	3	2 + Evap/Cond Grooved Tubes	4.07	0.58	4.65	267.59	10%
	4	3 + Increase Evap/Cond Coil Area	17.74	11.83	29.57	297.15	15%
	5	4 + Variable Speed Compressor	60.00	40.00	100.00	397.15	25%
	6	5 + Brushless D.C. Fan Motor	64.58	0.00	64.58	461.73	25%
5	7	3 + Incr Compressor EER to 11.5	20.60	0.00	20.60	288.19	30%
6	8	7 + Increase Evap/Cond Coil Area	18.45	12.30	30.75	318.94	15%
	9	8 + Variable Speed Compressor	60.00	40.00	100.00	418.94	25%
7	10	9 + Brushless D.C. Fan Motor	64.58	0.00	64.58	483.52	25%

Without Reverse Cycle and With Louvered Sides, 14,000 to 19,999 Btu/h

Std Level	Design No.	Design Option	Variable Cost	Capital Cost	Total Increment.	Total Cost	Uncert.
1	0	Baseline	288.29	41.18	-	329.47	-
	1	0 + Add Subcooler	3.85	0.55	4.40	333.88	10%
2,3	2	1 + Incr Compressor EER to 10.8	12.24	0.00	12.24	346.12	5%
4	3	2 + Incr Compressor EER to 11.16	5.51	0.00	5.51	351.63	10%
	4	3 + Variable Speed Compressor	60.00	40.00	100.00	451.63	25%
	5	4 + Increase Evap/Cond Coil Area	54.34	36.22	90.56	542.19	15%
	6	5 + Brushless D.C. Fan Motor	78.33	0.00	78.33	620.52	25%
5,6	7	2 + Incr Compressor EER to 12.0	25.61	0.00	25.61	371.73	30%
	8	7 + Condenser Grooved Tubes	3.61	0.52	4.13	375.85	10%
	9	8 + Variable Speed Compressor	60.00	40.00	100.00	475.85	25%
	10	9 + Increase Evap/Cond Coil Area	55.33	36.88	92.21	568.05	15%
7	11	10 + Brushless D.C. Fan Motor	78.33	0.00	78.33	646.38	25%

Table A.5 Total Manufacturing Costs for Room Air Conditioners (by Design Option) Cont'd**Without Reverse Cycle and With Louvered Sides, greater than 20,000 Btu/h**

Std Level	Design No.	Design Option	Variable Cost	Capital Cost	Total Increment.	Total Cost	Uncert.
1,2,3	0	Baseline	356.63	50.95	-	407.58	-
	1	0 + Add Subcooler	3.85	0.55	4.40	411.99	10%
	2	1 + Incr Compressor EER to 10.9	5.55	0.00	5.55	417.53	5%
4	3	2 + Incr Compressor EER to 11.22	6.12	0.00	6.12	423.65	10%
	4	3 + Variable Speed Compressor	60.00	40.00	100.00	523.65	25%
	5	4 + Increase Evap/Cond Coil Area	30.71	20.48	51.19	574.84	15%
	6	5 + Brushless D.C. Fan Motor	87.50	0.00	87.50	662.34	25%
5	7	2 + Incr Compressor EER to 12.0	30.39	0.00	30.39	447.92	30%
6	8	7 + Variable Speed Compressor	60.00	40.00	100.00	547.92	25%
	9	8 + Increase Evap/Cond Coil Area	31.85	21.24	53.09	601.01	15%
7	10	9 + Brushless D.C. Fan Motor	87.50	0.00	87.5	688.51	25%

Without Reverse Cycle and Without Louvered Sides, Less Than 6000 Btu/h

Std Level	Design No.	Design Option	Variable Cost	Capital Cost	Total Increment.	Total Cost	Uncert.
	0	Baseline	157.18	22.45	-	179.63	-
	1	0 + Evap/Cond Enhanced Fins	0.71	0.10	0.81	180.44	10%
1,2	2	1 + PSC Fan Motor	3.00	0.00	3.00	183.44	5%
	3	2 + Evap/Cond Grooved Tubes	2.41	0.34	2.75	186.19	10%
3	4	3 + Add Subcooler	3.10	0.44	3.54	189.73	10%
4	5	4 + Incr Compressor EER to 11.0	1.65	0.00	1.65	191.38	5%
	6	5 + Increase Evap/Cond Coil Area	16.05	10.70	26.75	218.13	15%
	7	6 + Variable Speed Compressor	60.00	40.00	100.00	318.13	25%
	8	7 + Brushless D.C. Fan Motor	60.00	0.00	60.00	378.13	25%
5	9	5 + Incr Compressor EER to 11.5	11.67	0.00	11.67	203.05	30%
6	10	9 + Increase Evap/Cond Coil Area	16.09	10.73	26.82	229.87	15%
	11	10 + Variable Speed Compressor	60.00	40.00	100.00	329.87	25%
7	12	11 + Brushless D.C. Fan Motor	60.00	0.00	60.00	389.87	25%

Table A.5 Total Manufacturing Costs for Room Air Conditioners (by Design Option) Cont'd

Without Reverse Cycle and Without Louvered Sides, 6000 to 7999 Btu/h							
Std Level	Design No.	Design Option	Variable Cost	Capital Cost	Total Increm.	Total Cost	Uncert.
1	0	Baseline	175.28	25.04	-	200.32	-
	1	0 + Evap/Cond Enhanced Fins	0.98	0.14	1.12	201.44	10%
2	2	1 + PSC Fan Motor	3.00	0.00	3.00	204.44	5%
	3	2 + Add Subcooler	3.10	0.44	3.54	207.98	10%
3,4	4	3 + Evap/Cond Grooved Tubes	3.61	0.52	4.13	212.11	10%
	5	4 + Increase Evap/Cond Coil Area	16.84	11.23	28.07	240.18	15%
	6	5 + Variable Speed Compressor	60.00	40.00	100.00	340.18	25%
	7	6 + Brushless D.C. Fan Motor	61.83	0.00	61.83	402.01	25%
5	8	4 + Incr Compressor EER to 11.5	13.56	0.00	13.56	225.67	30%
6	9	8 + Increase Evap/Cond Coil Area	17.03	11.36	28.39	254.06	15%
	10	9 + Variable Speed Compressor	60.00	40.00	100.00	354.06	25%
7	11	10 + Brushless D.C. Fan Motor	61.83	0.00	61.83	415.89	25%

Without Reverse Cycle and Without Louvered Sides, 8000 to 13,999 Btu/h							
Std Level	Design No.	Design Option	Variable Cost	Capital Cost	Total Increm.	Total Cost	Uncert.
1	0	Baseline	224.32	32.04	-	256.36	-
	1	0 + Add Subcooler	1.70	0.24	1.94	258.30	10%
2	2	1 + Incr Compressor EER to 10.7	4.64	0.00	4.64	262.94	5%
3,4	3	2 + Evap/Cond Grooved Tubes	4.07	0.58	4.65	267.59	10%
	4	3 + Increase Evap/Cond Coil Area	17.74	11.83	29.57	297.15	15%
	5	4 + Variable Speed Compressor	60.00	40.00	100.00	397.15	25%
	6	5 + Brushless D.C. Fan Motor	64.58	0.00	64.58	461.73	25%
5	7	3 + Incr Compressor EER to 11.5	20.60	0.00	20.60	288.19	30%
6	8	7 + Increase Evap/Cond Coil Area	18.45	12.30	30.75	318.94	15%
	9	8 + Variable Speed Compressor	60.00	40.00	100.00	418.94	25%
7	10	9 + Brushless D.C. Fan Motor	64.58	0.00	64.58	483.52	25%

Table A.5 Total Manufacturing Costs for Room Air Conditioners (by Design Option) Cont'd

Without Reverse Cycle and Without Louvered Sides, 14,000 to 19,999 Btu/h

Std Level	Design No.	Design Option	Variable Cost	Capital Cost	Total Increment.	Total Cost	Uncert.
1	0	Baseline	288.29	41.18	-	329.47	-
	1	0 + Add Subcooler	3.85	0.55	4.40	333.88	10%
2,3	2	1 + Incr Compressor EER to 10.8	12.24	0.00	12.24	346.12	5%
4	3	2 + Incr Compressor EER to 11.16	5.51	0.00	5.51	351.63	10%
	4	3 + Variable Speed Compressor	60.00	40.00	100.00	451.63	25%
	5	4 + Increase Evap/Cond Coil Area	54.34	36.22	90.56	542.19	15%
	6	5 + Brushless D.C. Fan Motor	78.33	0.00	78.33	620.52	25%
5,6	7	2 + Incr Compressor EER to 12.0	25.61	0.00	25.61	371.73	30%
	8	7 + Condenser Grooved Tubes	3.61	0.52	4.13	375.85	10%
	9	8 + Variable Speed Compressor	60.00	40.00	100.00	475.85	25%
	10	9 + Increase Evap/Cond Coil Area	55.33	36.88	92.21	568.05	15%
7	11	10 + Brushless D.C. Fan Motor	78.33	0.00	78.33	646.38	25%

Without Reverse Cycle and Without Louvered Sides, Greater Than 20,000 Btu/h

Std Level	Design No.	Design Option	Variable Cost	Capital Cost	Total Increment.	Total Cost	Uncert.
1,2,3	0	Baseline	356.63	50.95	-	407.58	-
	1	0 + Add Subcooler	3.85	0.55	4.40	411.99	10%
	2	1 + Incr Compressor EER to 10.9	5.55	0.00	5.55	417.53	5%
4	3	2 + Incr Compressor EER to 11.22	6.12	0.00	6.12	423.65	10%
	4	3 + Variable Speed Compressor	60.00	40.00	100.00	523.65	25%
	5	4 + Increase Evap/Cond Coil Area	30.71	20.48	51.19	574.84	15%
	6	5 + Brushless D.C. Fan Motor	87.50	0.00	87.50	662.34	25%
5	7	2 + Incr Compressor EER to 12.0	30.39	0.00	30.39	447.92	30%
6	8	7 + Variable Speed Compressor	60.00	40.00	100.00	547.92	25%
	9	8 + Increase Evap/Cond Coil Area	31.85	21.24	53.09	601.01	15%
7	10	9 + Brushless D.C. Fan Motor	87.50	0.00	87.5	688.51	25%

Table A.5 Total Manufacturing Costs for Room Air Conditioners (by Design Option) Cont'd

With Reverse Cycle and With Louvered Sides

Std Level	Design No.	Design Option	Variable Cost	Capital Cost	Total Increm.	Total Cost	Uncert.
1	0	Baseline	288.29	41.18	-	329.47	-
	1	0 + Add Subcooler	3.85	0.55	4.40	333.88	10%
2,3	2	1 + Incr Compressor EER to 10.8	12.24	0.00	12.24	346.12	5%
4	3	2 + Incr Compressor EER to 11.16	5.51	0.00	5.51	351.63	10%
	4	3 + Variable Speed Compressor	60.00	40.00	100.00	451.63	25%
	5	4 + Increase Evap/Cond Coil Area	54.34	36.22	90.56	540.27	15%
	6	5 + Brushless D.C. Fan Motor	78.33	0.00	78.33	618.60	25%
5	7	2 + Incr Compressor EER to 12.0	25.61	0.00	25.61	371.73	30%
	8	7 + Condenser Grooved Tubes	3.61	0.52	4.13	375.85	10%
6	9	8 + Variable Speed Compressor	60.00	40.00	100.00	475.85	25%
	10	9 + Increase Evap/Cond Coil Area	55.33	36.88	92.21	565.86	15%
7	11	10 + Brushless D.C. Fan Motor	78.33	0.00	78.33	644.19	25%

With Reverse Cycle and Without Louvered Sides

Std Level	Design No.	Design Option	Variable Cost	Capital Cost	Total Increm.	Total Cost	Uncert.
1	0	Baseline	224.32	32.04	-	256.36	-
	1	0 + Add Subcooler	1.70	0.24	1.94	258.30	10%
2	2	1 + Incr Compressor EER to 10.7	4.64	0.00	4.64	262.94	5%
3,4	3	2 + Evap/Cond Grooved Tubes	4.07	0.58	4.65	267.59	10%
	4	3 + Increase Evap/Cond Coil Area	17.74	11.83	29.57	296.44	15%
	5	4 + Variable Speed Compressor	60.00	40.00	100.00	396.44	25%
	6	5 + Brushless D.C. Fan Motor	64.58	0.00	64.58	461.02	25%
5	7	3 + Incr Compressor EER to 11.5	20.60	0.00	20.60	288.19	30%
6	8	7 + Increase Evap/Cond Coil Area	18.45	12.30	30.75	317.75	15%
	9	8 + Variable Speed Compressor	60.00	40.00	100.00	417.75	25%
7	10	9 + Brushless D.C. Fan Motor	64.58	0.00	64.58	482.33	25%

APPENDIX B. LBL-REM INPUT DATA: AIR CONDITIONING

The complete input listing is available on electronic medium in ASCII format. The input database includes demographic, economic, and engineering data.

The following is the regular LBL-REM input for air conditioning equipment.

For standards cases, simply replace the input values for two variables in each class of each product regulated. The two variables are labelled: "first year for standard" and "UEC of standard." For example, for room air conditioner standards taking effect in 1996, change the lines "first year for standard = 2031" to "first year for standard = 1996" and enter the appropriate maximum UEC values in the lines "UEC of standard" for each class.

AIR COND.

total saturation = 1.00
 elec price multiplier = 1.00
 gas price multiplier = 1.00
 ncalc = 2
 ndr1 (1, read drate & curve) = 1
 nv1 (# of eun inputs) = 3
 nv5 (# of cap inputs) = 2
 nv2 (# of peq inputs) = 0
 nv4 (# of usage inputs) = 0
 ndis (year to forecast eff) = 13
 nv3 (# of tin inputs) = 3

----- UEC of stock unit in base year by fuel type i (MMBTU/yr) -----

1	2	3	4	5	
13.810	36.40	34.27	0.000	0.000	** SF **
13.810	36.40	34.27	0.000	0.000	** MF **
13.810	36.40	34.27	0.000	0.000	** MB **

----- Purchase price of a reference unit (\$1990) -----

1	2	3	4	5	
471.51	1614.69	1827.75	0.00	0.00	** SF **
471.51	1614.69	1827.75	0.00	0.00	** MF **
471.51	1614.69	1827.75	0.00	0.00	** MB **

----- Relative UEC and Capacity of a reference unit to a stock unit -----

1	2	3	4	5	
0.8031	0.9809	1.0791	1.00	1.00	** re **
1.0000	1.1580	1.1200	1.00	1.00	** recap**

----- Base Year Saturations - c70 -----

1	2	3	4	5	6	
0.305	0.253	0.044	0.000	0.000	0.398	** SF **
0.329	0.210	0.042	0.000	0.000	0.419	** MF **
0.265	0.226	0.010	0.000	0.000	0.499	** MB **

----- Marginal Saturations for Replacement Units - cn(m=1) -----

1	2	3	4	5	6	
0.370	0.385	0.020	0.000	0.000	0.225	** SF **
0.480	0.160	0.015	0.000	0.000	0.345	** MF **
0.710	0.070	0.005	0.000	0.000	0.215	** MB **

----- Marginal Saturations for New Houses - cn(m=2) -----

1	2	3	4	5	6	
0.100	0.283	0.250	0.000	0.000	0.367	** SF **
0.240	0.495	0.060	0.000	0.000	0.205	** MF **
0.305	0.355	0.030	0.000	0.000	0.310	** MB **

----- Historical Shipments (from 1980 to 30 years back) -----

1 Room Air Conditioner									
2.433	2.726	2.654	2.157	1.945	2.395	3.739	4.106	3.965	4.407
4.654	4.314	3.390	3.297	2.704	2.393	2.039	1.473	1.238	1.208
1.271	1.314	1.305	1.301	1.335	1.023	1.008	.6940	0.272	0.175
2 Central Air Conditioner									
1.724	2.133	2.155	2.308	1.841	1.456	2.075	2.226	1.832	1.355
1.238	1.150	0.897	0.816	0.757	0.663	0.555	0.452	0.333	0.248
0.268	0.221	0.169	0.170	0.179	0.145	0.108	0.069	0.024	0.000
3 Heat Pump									
0.433	0.548	0.560	0.376	0.201	0.090	0.058	0.085	0.082	0.059
0.051	0.050	0.048	0.047	0.048	0.060	0.067	0.049	0.038	0.032
0.030	0.025	0.017	0.006	0.003	0.002	0.001	0.001	0.000	0.000

----- Retirement Function (from age 1 to 30 years) -----

for i 1									
.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
.0000	.0730	.1460	.1830	.1960	.1830	.1460	.0730	.0000	.0000
.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
for i 2 3									
.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0330	.1020	.1340
.1530	.1560	.1530	.1340	.1020	.0330	.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
15.0	12.0	14.0	0.0	0.0

----- Operating Cost Elasticities (for 5 fuel types and income) -----

1	2	3	4	5	6	
-0.20	0.00	0.00	0.00	0.00	0.17	** j=1 **
0.00	-0.40	0.00	0.00	0.00	0.00	** j=2 **
0.00	0.00	-0.40	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 **
.599	1.20	1.20	0.00	0.00	-0.50	** j=6 **

----- Real Interest Rate for calc of Price Elast. (for 5 fuel types) -----

1	2	3	4	5	
0.15	0.18	0.18	0.00	0.00	** j=1 **
0.15	0.12	0.00	0.00	0.00	** j=2 **
0.00	0.00	0.12	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	
-0.20	0.00	0.00	0.00	0.00	** j=1 **
0.00	-0.20	0.00	0.00	0.00	** j=2 **
0.00	0.00	-0.20	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 **
0.30	0.30	0.30	0.00	0.00	** j=6 **

----- Discount Rates for Replacement Units (m=1) -----

1	2	3	4	5	
0.2150	0.1570	0.1630	0.0000	0.0000	** SF **
0.0500	-0.0040	0.0150	0.0000	0.0000	** MF **
0.1130	0.0540	0.0650	0.0000	0.0000	** MB **

----- Discount Rates for New Units (m=2) -----

1	2	3	4	5	
0.2130	0.1550	0.1660	0.0000	0.0000	** SF **
0.0460	-0.0080	0.0140	0.0000	0.0000	** MF **
0.0990	0.0440	0.0550	0.0000	0.0000	** MB **

----- Cost-Efficiency Curve Parameters -----

1	2	3	4	5	
0.5544	0.2414	0.2538	0.00	0.00	** einf **
5.0813	1.4210	1.7388	0.00	0.00	** ealfa **

----- Thermal Integrity of New Units -----

1	2	3	4	5	
0.989	0.987	0.975	1.000	1.000	** SF **
0.998	0.997	0.986	1.000	1.000	** MF **
0.990	0.980	0.935	1.000	1.000	** MB **

----- Historical Relative Energy Use (eun) for New Units -----

i	1	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
1	0	.9561	.9454	.9259	.9024	.8766	.8513	.8260	.8006	.7753	.7500	.7500	.7500
2	0	.8959	.8387	.8268	.8048	.7902	.7858	.7770	.7544	.7317	.7091	.6864	.6638
3	0	.8740	.8444	.8177	.7964	.7862	.7654	.7447	.7239	.7032	.6824	.6617	.6409

----- Historical Relative Capacity (cap) for New Units -----

i	1	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
2	0	0.841	0.836	0.807	0.809	0.817	0.817	0.817	0.817	0.817	0.817	0.817	0.817
3	0	0.828	0.824	0.799	0.802	0.788	0.788	0.788	0.788	0.788	0.788	0.788	0.788

of products in room A/C = 1

product type id# = 10
product name = RAC (Room A/C)
end-use id# = 3
fuel type id# = 1
number of classes = 12

----- the 1st class -----

class id# = 39
class name = 6L (Room A/C < 6K Btuh with louvres)
discount rate = 0.76
first year to forecast UEC = 1989
first year for standard = 2031
UEC of standard = 397.3
conversion (Kwh-MMBTU&usage) = .003412

----- Historical energy factors (AHAM scaled to baseline)

1981	1982	1983	1984	1985	1986	1987	1988	1989
6.68	6.76	6.90	7.08	7.29	7.38	7.63	7.79	8.02

----- Adjusted volumes (1981-2030) (5869.1/1000*750/365 baseline capc*hr/(1000*365))

12.0598	12.0598	12.0598	12.0598	12.0598	12.0598	12.0598	12.0598	12.0598	12.0598
12.0598	12.0598	12.0598	12.0598	12.0598	12.0598	12.0598	12.0598	12.0598	12.0598
12.0598	12.0598	12.0598	12.0598	12.0598	12.0598	12.0598	12.0598	12.0598	12.0598
12.0598	12.0598	12.0598	12.0598	12.0598					

----- Fraction of market share (1981-2030)

1 = 1 2 3

.2756	.2756	.2756	.2756	.2756	.2756	.2756	.2756	.2756	.2756
.2756	.2756	.2756	.2756	.2756	.2756	.2756	.2756	.2756	.2756
.2756	.2756	.2756	.2756	.2756	.2756	.2756	.2756	.2756	.2756
.2756	.2756	.2756	.2756	.2756					

----- UEC (Kwh) & Purchase Price (\$1990) data

Price	Kwh
287.91	532.1
288.89	501.5
292.68	470.3
296.23	445.7
301.55	421.8
303.34	414.6
330.33	398.5
320.46	397.3

342.52 382.3
430.15 344.0
507.95 337.7

----- Shipment Distribution (source: AHAM directory)

EFF	Units
8.00	50.0
8.10	2.0
8.40	1.0
8.50	4.0
8.70	15.0
8.80	1.0
9.00	31.0
9.40	1.0
9.50	1.0
9.60	1.0
10.00	5.0

----- the 2nd class -----

class id# = 40
class name = 6N (Room A/C < 6K Btuh w/o louvres)
discount rate = 0.76
first year to forecast UEC = 1989
first year for standard = 2031
UEC of standard = 412.1
conversion (Kwh-MMBTU&usage) = .003412

----- Historical energy factors (AHAM scaled to baseline)

1981	1982	1983	1984	1985	1986	1987	1988	1989
6.43	6.50	6.64	6.81	7.01	7.10	7.34	7.50	7.72

----- Adjusted volumes (1981-2030) (5861.6/1000*750/365)

12.0444	12.0444	12.0444	12.0444	12.0444	12.0444	12.0444	12.0444	12.0444	12.0444
12.0444	12.0444	12.0444	12.0444	12.0444	12.0444	12.0444	12.0444	12.0444	12.0444
12.0444	12.0444	12.0444	12.0444	12.0444	12.0444	12.0444	12.0444	12.0444	12.0444
12.0444	12.0444	12.0444	12.0444	12.0444	12.0444	12.0444	12.0444	12.0444	12.0444

----- Fraction of market share (1981-2030)

l	1	2	3
.0003	.0003	.0003	.0003
.0003	.0003	.0003	.0003
.0003	.0003	.0003	.0003
.0003	.0003	.0003	.0003

----- UEC (Kwh) & Purchase Price (\$1990) data

Price	Kwh
287.91	552.0
288.89	519.2
292.68	487.9
296.23	461.9
301.55	436.9

303.34	429.5
330.28	412.9
320.46	412.1
342.48	396.1
430.13	356.5
507.92	350.1

----- Shipment Distribution

EFF	Units
8.70	7.0
9.40	2.0
9.50	1.0

----- the 3rd class -----

class id# = 41
class name = 8L (Room A/C 6K to 8K Btuh with louvres)
discount rate = 0.35
first year to forecast UEC = 1989
first year for standard = 2031
UEC of standard = 553.4
conversion (Kwh-MMBTU&usage) = .003412

----- Historical energy factors (AHAM scaled to baseline)

1981	1982	1983	1984	1985	1986	1987	1988	1989
6.83	6.90	7.05	7.23	7.44	7.54	7.79	7.96	8.20

----- Adjusted volumes (1981-2030) (7562.2/1000*750/365)

15.5388	15.5388	15.5388	15.5388	15.5388	15.5388	15.5388	15.5388	15.5388	15.5388
15.5388	15.5388	15.5388	15.5388	15.5388	15.5388	15.5388	15.5388	15.5388	15.5388
15.5388	15.5388	15.5388	15.5388	15.5388	15.5388	15.5388	15.5388	15.5388	15.5388
15.5388	15.5388	15.5388	15.5388	15.5388					

----- Fraction of market share (1981-2030)

! = 1 2 3

.1761	.1761	.1761	.1761	.1761	.1761	.1761	.1761	.1761	.1761
.1761	.1761	.1761	.1761	.1761	.1761	.1761	.1761	.1761	.1761
.1761	.1761	.1761	.1761	.1761	.1761	.1761	.1761	.1761	.1761
.1761	.1761	.1761	.1761	.1761					

----- UEC (Kwh) & Purchase Price (\$1990) data

Price	Kwh
396.22	670.9
398.05	653.8
403.33	608.6
407.67	591.7
415.53	579.5
450.03	553.8
439.49	553.4
466.36	528.3
573.95	475.5
672.99	467.1

----- Shipment Distribution

EFF	Units
8.50	11.0
8.60	1.0
8.70	41.0
8.90	2.0
9.00	30.0
9.10	2.0
9.20	4.0
9.40	1.0
9.50	9.0
9.80	1.0
10.00	2.0
11.00	1.0

----- the 4th class -----

class id# = 42
class name = 8N (Room A/C 6K to 8K Btuh w/o louveres)
discount rate = 0.35
first year to forecast UEC = 1989
first year for standard = 2031
UEC of standard = 573.6
conversion (Kwh-MMBTU&usage) = .003412

----- Historical energy factors (AHAM scaled to baseline)

1981	1982	1983	1984	1985	1986	1987	1988	1989
6.58	6.66	6.80	6.98	7.18	7.27	7.52	7.67	7.91

----- Adjusted volumes (1981-2030) (7554.8/1000*750/365)

15.5236	15.5236	15.5236	15.5236	15.5236	15.5236	15.5236	15.5236	15.5236	15.5236
15.5236	15.5236	15.5236	15.5236	15.5236	15.5236	15.5236	15.5236	15.5236	15.5236
15.5236	15.5236	15.5236	15.5236	15.5236	15.5236	15.5236	15.5236	15.5236	15.5236
15.5236	15.5236	15.5236	15.5236	15.5236					

----- Fraction of market share (1981-2030)

1 = 1 2 3

.0070	.0070	.0070	.0070	.0070	.0070	.0070	.0070	.0070	.0070
.0070	.0070	.0070	.0070	.0070	.0070	.0070	.0070	.0070	.0070
.0070	.0070	.0070	.0070	.0070	.0070	.0070	.0070	.0070	.0070
.0070	.0070	.0070	.0070	.0070					

----- UEC (Kwh) & Purchase Price (\$1990) data

Price	Kwh
396.22	695.0
398.05	677.2
403.33	633.4
407.67	614.3
415.53	600.7
449.92	574.5
439.49	573.6
466.28	547.7

573.90 492.9
672.92 484.9

----- Shipment Distribution

EFF	Units
8.70	7.0
9.40	2.0
9.50	1.0

----- the 5th class -----

class id# = 43
class name = 14L (Room A/C 8K to 14K Btuh with louvres)
discount rate = 0.34
first year to forecast UEC = 1989
first year for standard = 2031
UEC of standard = 826.2
conversion (Kwh-MMBTU&usage) = .003412

----- Historical energy factors (AHAM scaled to baseline)

1981	1982	1983	1984	1985	1986	1987	1988	1989
7.54	7.62	7.78	7.98	8.22	8.33	8.60	8.79	9.05

----- Adjusted volumes (1981-2030) (12140.9/1000*750/365)

24.9471	24.9471	24.9471	24.9471	24.9471	24.9471	24.9471	24.9471	24.9471	24.9471
24.9471	24.9471	24.9471	24.9471	24.9471	24.9471	24.9471	24.9471	24.9471	24.9471
24.9471	24.9471	24.9471	24.9471	24.9471	24.9471	24.9471	24.9471	24.9471	24.9471
24.9471	24.9471	24.9471	24.9471	24.9471	24.9471	24.9471	24.9471	24.9471	24.9471

----- Fraction of market share (1981-2030)

l = 1 2 3

.2956	.2956	.2956	.2956	.2956	.2956	.2956	.2956	.2956	.2956
.2956	.2956	.2956	.2956	.2956	.2956	.2956	.2956	.2956	.2956
.2956	.2956	.2956	.2956	.2956	.2956	.2956	.2956	.2956	.2956
.2956	.2956	.2956	.2956	.2956					

----- UEC (Kwh) & Purchase Price (\$1990) data

Price	Kwh
504.00	976.0
506.52	938.1
514.77	906.4
523.30	880.8
556.71	826.2
559.40	814.1
616.11	760.5
695.34	684.5
811.93	674.5

----- Shipment Distribution

EFF	Units
9.00	138.0
9.10	21.0

9.20	3.0
9.30	9.0
9.40	7.0
9.50	34.0
9.60	2.0
9.70	4.0
10.00	1.0
10.20	2.0
10.50	3.0
11.00	1.0
11.60	3.0
12.00	4.0

----- the 6th class -----

class id# = 44
class name = 14N (Room A/C 8K to 14K Btuh w/o louvres)
discount rate = 0.34
first year to forecast UEC = 1989
first year for standard = 2031
UEC of standard = 858.5
conversion (Kwh-MMBTU&usage) = .003412

----- Historical energy factors (AHAM scaled to baseline)

1981	1982	1983	1984	1985	1986	1987	1988	1989
7.27	7.35	7.51	7.70	7.93	8.03	8.30	8.47	8.73

----- Adjusted volumes (1981-2030) (12190.2/1000*750/365)

25.0484	25.0484	25.0484	25.0484	25.0484	25.0484	25.0484	25.0484	25.0484	25.0484
25.0484	25.0484	25.0484	25.0484	25.0484	25.0484	25.0484	25.0484	25.0484	25.0484
25.0484	25.0484	25.0484	25.0484	25.0484	25.0484	25.0484	25.0484	25.0484	25.0484
25.0484	25.0484	25.0484	25.0484	25.0484	25.0484	25.0484	25.0484	25.0484	25.0484

----- Fraction of market share (1981-2030)

1	2	3								
.0239	.0239	.0239	.0239	.0239	.0239	.0239	.0239	.0239	.0239	.0239
.0239	.0239	.0239	.0239	.0239	.0239	.0239	.0239	.0239	.0239	.0239
.0239	.0239	.0239	.0239	.0239	.0239	.0239	.0239	.0239	.0239	.0239
.0239	.0239	.0239	.0239	.0239						

----- UEC (Kwh) & Purchase Price (\$1990) data

Price	Kwh
504.00	1015.7
506.52	968.6
514.77	943.2
523.30	918.1
556.71	858.5
559.19	848.1
614.74	792.1
695.17	712.9
811.55	702.8

----- Shipment Distribution

EFF	Units
8.50	13.0
8.70	8.0
8.80	1.0
9.20	6.0

----- the 7th class -----

class id# = 45
class name = 20L (Room A/C 14K to 20K Btuh with louvres)
discount rate = 0.54
first year to forecast UEC = 1989
first year for standard = 2031
UEC of standard = 1218.9
conversion (Kwh-MMBTU&usage) = .003412

----- Historical energy factors (AHAM scaled to baseline)

1981	1982	1983	1984	1985	1986	1987	1988	1989
7.27	7.35	7.51	7.70	7.93	8.03	8.30	8.47	8.73

----- Adjusted volumes (1981-2030) (18113.3/1000*750/365)

37.1755	37.1755	37.1755	37.1755	37.1755	37.1755	37.1755	37.1755	37.1755	37.1755
37.1755	37.1755	37.1755	37.1755	37.1755	37.1755	37.1755	37.1755	37.1755	37.1755
37.1755	37.1755	37.1755	37.1755	37.1755	37.1755	37.1755	37.1755	37.1755	37.1755
37.1755	37.1755	37.1755	37.1755	37.1755	37.1755	37.1755	37.1755	37.1755	37.1755

----- Fraction of market share (1981-2030)

l = 1 2 3

.1313	.1313	.1313	.1313	.1313	.1313	.1313	.1313	.1313	.1313
.1313	.1313	.1313	.1313	.1313	.1313	.1313	.1313	.1313	.1313
.1313	.1313	.1313	.1313	.1313	.1313	.1313	.1313	.1313	.1313
.1313	.1313	.1313	.1313	.1313					

----- UEC (Kwh) & Purchase Price (\$1990) data

Price	Kwh
627.98	1508.0
635.69	1446.4
653.19	1344.7
669.21	1308.7
684.85	1229.0
695.90	1218.9
777.58	1177.9
847.01	1097.0
936.77	1033.9
988.64	998.9

----- Shipment Distribution

EFF	Units
8.80	25.0
9.00	29.0
9.10	1.0

9.20	20.0
9.30	1.0
9.40	1.0
9.50	7.0
10.00	4.0
10.20	2.0
10.50	1.0

----- the 8th class -----

class id# = 46
class name = 20N (Room A/C 14K to 20K Btuh w/o louvres)
discount rate = 0.54
first year to forecast UEC = 1989
first year for standard = 2031
UEC of standard = 1251.5
conversion (Kwh-MMBTU&usage) = .003412

----- Historical energy factors (AHAM scaled to baseline)

1981	1982	1983	1984	1985	1986	1987	1988	1989
6.98	7.06	7.21	7.39	7.61	7.71	7.97	8.14	8.38

----- Adjusted volumes (1981-2030) (18103.3/1000*750/365)

37.0498	37.0498	37.0498	37.0498	37.0498	37.0498	37.0498	37.0498	37.0498	37.0498
37.0498	37.0498	37.0498	37.0498	37.0498	37.0498	37.0498	37.0498	37.0498	37.0498
37.0498	37.0498	37.0498	37.0498	37.0498	37.0498	37.0498	37.0498	37.0498	37.0498
37.0498	37.0498	37.0498	37.0498	37.0498	37.0498	37.0498	37.0498	37.0498	37.0498

----- Fraction of market share (1981-2030)

1	2	3							
.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003
.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003
.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003
.0003	.0003	.0003	.0003	.0003					

----- UEC (Kwh) & Purchase Price (\$1990) data

Price	Kwh
627.98	1565.9
635.69	1493.4
653.19	1387.7
669.21	1351.5
684.85	1264.3
695.90	1251.5
777.58	1216.4
847.01	1126.3
935.77	1067.3
988.50	1032.5

----- Shipment Distribution

EFF	Units
8.50	13.0
8.70	8.0

8.80	1.0
9.20	6.0

----- the 9th class -----

class id# = 47
class name = >20L (Room A/C over 20K Btuh with louvres)
discount rate = 0.38
first year to forecast UEC = 1989
first year for standard = 2031
UEC of standard = 1912.2
conversion (Kwh-MMBTU&usage) = .003412

----- Historical energy factors (AHAM scaled to baseline)

1981	1982	1983	1984	1985	1986	1987	1988	1989
6.72	6.80	6.94	7.12	7.33	7.43	7.67	7.83	8.07

----- Adjusted volumes (1981-2030) (24555.0/1000*750/365)

50.4555	50.4555	50.4555	50.4555	50.4555	50.4555	50.4555	50.4555	50.4555	50.4555
50.4555	50.4555	50.4555	50.4555	50.4555	50.4555	50.4555	50.4555	50.4555	50.4555
50.4555	50.4555	50.4555	50.4555	50.4555	50.4555	50.4555	50.4555	50.4555	50.4555
50.4555	50.4555	50.4555	50.4555	50.4555	50.4555	50.4555	50.4555	50.4555	50.4555

----- Fraction of market share (1981-2030)

l = 1	2	3								
.0697	.0697	.0697	.0697	.0697	.0697	.0697	.0697	.0697	.0697	.0697
.0697	.0697	.0697	.0697	.0697	.0697	.0697	.0697	.0697	.0697	.0697
.0697	.0697	.0697	.0697	.0697	.0697	.0697	.0697	.0697	.0697	.0697
.0697	.0697	.0697	.0697	.0697						

----- UEC (Kwh) & Purchase Price (\$1990) data

Price	Kwh
864.79	2214.8
873.76	2131.0
885.53	2081.2
898.51	2028.0
928.38	1912.2
1031.65	1825.2
1046.22	1721.0
1159.16	1640.2
1252.32	1610.7

----- Shipment Distribution

EFF	Units
8.20	29.0
8.30	8.0
8.50	6.0
8.70	3.0
9.00	10.0
9.10	3.0
9.20	6.0

----- the 10th class -----

class id# = 48
class name = >20N (Room A/C over 20K Btuh w/o louvres)
discount rate = 0.38
first year to forecast UEC = 1989
first year for standard = 2031
UEC of standard = 1978.3
conversion (Kwh-MMBTU&usage) = .003412

----- Historical energy factors (AHAM scaled to baseline)

1981	1982	1983	1984	1985	1986	1987	1988	1989
6.49	6.56	6.70	6.87	7.07	7.17	7.41	7.56	7.79

----- Adjusted volumes (1981-2030) (24540.9/1000*750/365)

50.4265	50.4265	50.4265	50.4265	50.4265	50.4265	50.4265	50.4265	50.4265	50.4265
50.4265	50.4265	50.4265	50.4265	50.4265	50.4265	50.4265	50.4265	50.4265	50.4265
50.4265	50.4265	50.4265	50.4265	50.4265	50.4265	50.4265	50.4265	50.4265	50.4265
50.4265	50.4265	50.4265	50.4265	50.4265	50.4265	50.4265	50.4265	50.4265	50.4265

----- Fraction of market share (1981-2030)

l = 1 2 3

.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003
.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003
.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003
.0003	.0003	.0003	.0003	.0003					

----- UEC (Kwh) & Purchase Price (\$1990) data

Price	Kwh
845.25	2293.5
854.02	2205.9
865.51	2153.7
878.20	2098.5
907.40	1978.3
1008.34	1888.6
1022.58	1780.4
1132.41	1699.6
1223.89	1670.0

----- Shipment Distribution

EFF	Units
8.50	13.0
8.70	8.0
8.80	1.0
9.20	6.0

----- the 11th class -----

class id# = 49
class name = HPL (Heat pump room A/C with louvres)
discount rate = 0.41
first year to forecast UEC = 1989
first year for standard = 2031

UEC of standard = 1258.8
conversion (Kwh-MMBTU&usage) = .003412

----- Historical energy factors (AHAM scaled to baseline)

1981	1982	1983	1984	1985	1986	1987	1988	1989
7.04	7.12	7.26	7.45	7.67	7.77	8.03	8.20	8.45

----- Adjusted volumes (1981-2030) (18106.4/1000*750/365)

37.0646	37.0646	37.0646	37.0646	37.0646	37.0646	37.0646	37.0646	37.0646	37.0646
37.0646	37.0646	37.0646	37.0646	37.0646	37.0646	37.0646	37.0646	37.0646	37.0646
37.0646	37.0646	37.0646	37.0646	37.0646	37.0646	37.0646	37.0646	37.0646	37.0646
37.0646	37.0646	37.0646	37.0646	37.0646	37.0646	37.0646	37.0646	37.0646	37.0646

----- Fraction of market share (1981-2030)

l = 1 2 3

.0149	.0149	.0149	.0149	.0149	.0149	.0149	.0149	.0149	.0149
.0149	.0149	.0149	.0149	.0149	.0149	.0149	.0149	.0149	.0149
.0149	.0149	.0149	.0149	.0149	.0149	.0149	.0149	.0149	.0149
.0149	.0149	.0149	.0149	.0149					

----- UEC (Kwh) & Purchase Price (\$1990) data

Price	Kwh
801.76	1552.7
811.61	1477.2
833.94	1376.4
854.40	1339.5
874.36	1258.8
888.47	1241.4
992.76	1205.5
1023.99	1117.2
1194.87	1058.5
1301.26	1023.6

----- Shipment Distribution

EFF	Units
8.50	25.0
8.70	11.0
8.80	7.0
8.90	5.0
9.00	19.0
9.10	6.0
9.20	8.0
9.40	1.0
9.50	3.0
10.00	2.0
10.10	1.0

----- the 12th class -----

class id# = 50
class name = HPN (Heat pump room A/C w/o louvres)
discount rate = 0.41

first year to forecast UEC = 1989
 first year for standard = 2031
 UEC of standard = 879.6
 conversion (Kwh-MMBTU&usage) = .003412

----- Historical energy factors (AHAM scaled to baseline)
 1981 1982 1983 1984 1985 1986 1987 1988 1989
 7.09 7.17 7.32 7.51 7.74 7.84 8.10 8.27 8.52

----- Adjusted volumes (1981-2030) (12180.0/1000*750/365)
 25.0274 25.0274 25.0274 25.0274 25.0274 25.0274 25.0274 25.0274 25.0274 25.0274
 25.0274 25.0274 25.0274 25.0274 25.0274 25.0274 25.0274 25.0274 25.0274 25.0274
 25.0274 25.0274 25.0274 25.0274 25.0274 25.0274 25.0274 25.0274 25.0274 25.0274
 25.0274 25.0274 25.0274 25.0274 25.0274

----- Fraction of market share (1981-2030)
 1 = 1 2 3
 .0050 .0050 .0050 .0050 .0050 .0050 .0050 .0050 .0050 .0050
 .0050 .0050 .0050 .0050 .0050 .0050 .0050 .0050 .0050 .0050
 .0050 .0050 .0050 .0050 .0050 .0050 .0050 .0050 .0050 .0050
 .0050 .0050 .0050 .0050 .0050

----- UEC (Kwh) & Purchase Price (\$1990) data
 Price Kwh
 676.10 1040.1
 679.48 1004.3
 690.54 969.6
 701.99 940.8
 746.80 879.6
 749.84 870.3
 823.40 812.8
 932.39 731.5
 1088.33 721.4

----- Shipment Distribution
 EFF Units
 8.50 18.0
 8.70 7.0
 8.80 1.0
 9.00 2.0
 9.20 3.0

APPENDIX C. LBL MANUFACTURER IMPACT MODEL: ROOM AIR CONDITIONERS

C.1 INTRODUCTION

The Lawrence Berkeley Laboratory Manufacturer Impact Model (LBL-MIM) collects all the calculations necessary to determine the impact of a change in appliance efficiency standards on an industry's profitability and scale of operation into one spreadsheet. Volume A, Appendix C, of this Technical Support Document, provides an overview and description of the LBL-MIM. There is a description of the economic theory and a discussion of each of the model's modules. In this appendix, the LBL-MIM input data and model runs for the analysis of room air conditioners are described together.

C.1.1 Engineering Cost Data

The source of the engineering data is the Engineering Analysis performed in Chapter 1 of this volume. The data came from manufacturers of these products and/or discussions with industry consultants and other studies. The engineering data used in the model consist of several components:

1. The incremental unit variable cost incurred by the manufacturer for each design option such as raw materials, direct labor, purchased parts, and increased transportation costs that increases the efficiency of the appliance. The incremental variable cost is listed for each design option for each product class.
2. The annual unit energy consumption (UEC) associated with each design option for each product class.
3. 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 as one figure for each design option requiring capital expenditures; the single figure covers all of the product classes.

The engineering input data are also listed for each standards level being analyzed (a 1990 calibration case, a 1996 base case using the 1990 standards, and standard levels 1, 2, 3, etc. 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 standards levels instead. The engineering data used as inputs to the LBL-MIM 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. For a thorough description of the collection and meaning of the engineering data, see the Engineering Analysis (Chapter 1).

C.1.2 Industry Market Data

Industry Shipments

These data include annual industry shipments for the 1990 calibration case, the 1996 base case (using the 1990 standards), and the 1996 shipments for each of the standards levels. The 1990 shipments figure is based on data from AHAM.

Elasticities

Price and operating cost elasticities determine the effect on shipments of changes in appliance prices and operating costs. For room air conditioners, the price elasticity is estimated to be -0.33. The consumer discount rate is estimated to be 43.8%, which gives an operating cost elasticity of -0.18. The source is LBL.

Product Class Market Share

Generally, each of the product classes of an analyzed product has a share of the total market, and the market share, or unit sales, for each product class is an input to the model. For room air conditioners, the market shares range from 0.6% for room air conditioners with capacity less than 6000 Btu/h to 30% for room air conditioners with a capacity greater than 8000 Btu/h. Data are from 1989; the data source is AHAM.

Markups

Manufacturers charge different markups over variable cost for different product classes, resulting in different profit margins for different product classes. For room air conditioners, the estimated markups range from 1.28 for the smallest capacity model to 1.57 for the highest capacity model.

Initial Prices

The 1990 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 the Manufacturer and Engineering Analysis teams.

Energy Price

This figure is the ratio of the price of a 1990 kWh to a 1996 kWh. The source is the LBL-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 room air conditioners 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 ¹	6.8%	MIM calc. from public financial data ²
Interest rate on debt ¹	2.5%	MIM calc. from public financial data
Interest lost in cash ¹	1.0%	MIM calc. from public financial data
Rate of depreciation	17.7%	Public financial data
Tax rate	34.0%	Tax law

¹Cost of capital and interest rate are *real* rather than nominal.

²Public financial data include data from sources such as Value Line, Standard and Poor's, Moody's, individual company annual reports, and economic reports.

Table C.2 Other Financial Inputs

Variable	Value	Source
Cash	23.2%	Public financial data
Inventory and receivables	64.2%	Public financial data
Net depreciable assets	22.4%	Public financial data
General and administrative expenses	16.8%	Public financial data
Engineering expense	1.2%	Public financial data and industry sources ¹

¹Industry sources include consultants under contract to LBL and discussions with industry representatives.

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

Variable	Value	Source
Fixed part of all costs and depr. assets	11.5%	Industry sources
Fixed part of one-time capital costs	6.0%	Industry sources
Economic profit	1.84%	MIM est. from financial data
Debt/equity ratio	62.7%	Public financial data
Markup on typical model	1.38	Industry sources
Ratio of highest to lowest markup	2.00	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	8 years	MIM calculation
Percent additional 1-X capital	50%	MIM estimate
Age of replaced capital	6 years	Public financial data

The expenditure schedule above lists the costs incurred over time for preparations to meet the new standards. A percentage of the total cost is attributed to each year before the standards go into effect since that is when these expenses will occur.

C.2 LBL-MIM INPUTS AND OUTPUTS SHOWING THE PRIMARY SCENARIO

Table C.5 Room Air Conditioners Version of LBL-MIM

Control Panel

ROOM AIR CONDITIONERS CONTROL FACTORS	Scenario: Primary		Standard Level = 1		
	Input Value	Cntrl	Vari- ation	Progrm Value	Name
Price Elasticity	-0.330	0.00	100%	-0.330	IPE
Consumer Discount Rate	48.80%	0.00	100%	48.80%	RD
Equity Cost of Capital	0.068	0.00	10%	0.068	ECC
Economic Profit	0.018	0.00	1%	0.018	EP
L-R Fixed Part of Costs & Assets	0.115	0.00	50%	0.115	FCA
L-R Fixed Part of 1-X Cap. Cost	0.097	0.00	60%	0.097	F1X
One-Time Capital Costs	3.266	0.00	20%	3.266	CC.N
Unit Variable Cost Increase	\$4.26	0.00	30%	4.265	dVC.N
Elasticity Curve Parameter	0.000	0.00	30%	0.000	ro.N
Short Run Price Response to Demand	0.157	0.00	76%	0.157	SRPR
SUMMARY	NAECA	NEW	PRVIOUS	NEW	
	BASE	L-RUN	CHANGE	S-RUN	
Shipments	1.00	1.00	0.32%	1.00	
Price	\$299.75	\$300.25	0.17%	\$300.57	
Revenue (in \$M)	299.70	301.18	0.49%	301.40	
Net Income	17.16	17.13	-0.03	17.16	
ROE	8.56%	8.52%	-0.04%	8.54%	
Trys =			2.00		

Table C.6 Room Air Conditioners Version of LBL-MIM

The Monte Carlo Module

MONTE CARLO DETERMINATION OF STANDARD ERRORS OF ESTIMATES.

	Secnds/iteration =	2.54	time
	Iterations to go =	0.00	mn
ROOM AIR CONDITIONERS	Sample Size =	399.00	

	%dQ	%dP	%dR	dNI	dROE.N	dROE.S
Value	0.32%	0.17%	0.49%	-0.03	-0.04%	-0.03%
Means	-20.09%	89.41%	50.06%	-1.68	-2.55%	-7.91%
Std. Dev	16.01%	26.64%	31.10%	17.63	8.74%	66.11%
History	-0.20	0.75	0.39	-4.93	-0.03	-0.19
...	-0.45	1.31	0.26	-14.61	-0.07	0.52
Range	-0.44	0.71	-0.04	-20.28	-0.10	-0.09
Name	-0.08	0.82	0.67	2.22	-0.01	-0.10
Is	-0.05	0.74	0.65	9.63	0.01	-0.09
Carlo	-0.32	1.02	0.37	-23.37	-0.11	-0.23
	-0.26	1.13	0.57	-0.49	-0.02	-0.15
	-0.09	0.85	0.68	-0.09	-0.02	-0.11
	-0.30	0.65	0.16	-20.27	-0.10	-0.23
	-0.25	0.76	0.33	-17.63	-0.09	-0.21
	-0.05	0.75	0.66	38.73	0.13	0.05
	-0.13	1.09	0.82	14.33	0.05	-0.03
	-0.05	0.65	0.57	1.10	-0.01	-0.20
	-0.35	1.17	0.41	-6.84	-0.03	-0.15
	-0.06	0.83	0.72	16.94	0.04	-0.05
	-0.09	1.09	0.91	18.86	0.06	-0.05
	-0.09	0.66	0.51	1.26	-0.01	-0.25
	-0.07	0.65	0.54	16.36	0.06	0.00
	-0.16	0.93	0.62	-4.29	-0.02	-0.12
	-0.44	0.80	0.01	-31.62	-0.16	-0.51
	-0.38	0.87	0.17	-17.35	-0.09	-0.18
	-0.02	0.77	0.74	4.66	-0.01	-0.12
	-0.19	1.68	1.16	29.92	0.10	-0.03
	-0.12	0.98	0.74	19.13	0.06	-0.06
	-0.40	0.91	0.15	-22.46	-0.11	-0.19
	-0.15	1.08	0.76	3.50	0.00	-0.10
	-0.19	0.64	0.33	-8.06	-0.05	-0.20
	-0.04	0.70	0.63	5.78	0.00	-0.09
	-0.04	0.88	0.80	8.35	0.01	-0.07

Table C.7 Room Air Conditioners Version of LBL-MIM***The Accounting Module***

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

	1990	BASE '96	NEW '96	CHANGE
Revenue	294.87	299.70	301.18	0.5%
Expenses				
Cost of Goods Sold	212.75	217.12	218.56	0.7%
Selling & G & A	38.57	39.24	39.30	0.2%
Engineering	2.75	2.80	2.80	0.2%
Depreciation	12.01	12.01	12.01	NA
1-X Depreciation	0.00	0.40	0.41	NA
Total Expenses	266.09	271.57	273.09	0.6%
Earnings Before Interest & Taxes	28.78	28.13	28.08	-0.2%
Interest	2.72	2.10	2.10	0.2%
Earnings Before Taxes	26.06	26.03	25.98	-0.2%
Taxes	8.86	8.94	8.93	-0.2%
Net Income	17.20	17.09	17.05	-0.2%
Gross Margin	27.85%	27.56%	27.43%	-0.45%
Return on Sales	5.83%	5.70%	5.66%	-0.7%
Total Assets	323.83	325.98	327.03	0.3%
Return on Assets (w/intrst taxed)	5.87%	5.67%	5.64%	0.0
Equity	199.07	200.39	201.04	0.3%
Return on Equity	8.64%	8.53%	8.48%	0.0

ECONOMIC ANALYSIS

	1990	BASE '96	NEW '96	CHANGE
INCOME				
Shipments	1.00	1.00	1.00	0.3%
Price	\$296.08	\$299.75	\$300.25	0.2%
Revenue	294.87	299.70	301.18	0.5%
EXPENSE (W/ INTEREST)				
Fixed Costs	33.90	33.90	33.90	-9.2%
Variable Costs (w/ Q)	234.90	239.36	27.97	-11.5%
Total Expenses	268.81	273.27	61.87	-10.9%
ASSETS				
Cash	68.32	68.59	56.59	-10.8%
Inventories	189.42	190.18	190.79	0.3%
Depreciable	-768.60	-734.20	-639.76	-12.9%
Total Assets	323.83	325.98	327.03	0.3%

Table C.8 Room Air Conditioners Version of LBL-MIM

The Engineering Inputs Module

Increment in Additional UVC by Level and Class													
Baseline	0	1	2	3	4	5	6	7	8	9	10	11	12
6K-L	157.2	0.7	3.0	2.4	3.1	1.7	16.1	60.0	60.0	11.7	16.1	60.0	60.0
6K-NL	157.2	0.7	3.0	2.4	3.1	1.7	16.0	60.0	60.0	11.7	16.1	60.0	60.0
6K>L	175.3	1.0	3.0	3.1	3.6	16.8	60.0	61.8	13.6	17.0	60.0	61.8	
6K>NL	175.3	1.0	3.0	3.1	3.6	16.8	60.0	61.8	13.6	16.9	60.0	61.8	
8K>L	224.3	1.7	4.6	4.1	17.7	60.0	64.6	20.6	18.5	60.0	64.6		
8K>NL	224.3	1.7	4.6	4.1	17.5	60.0	64.6	20.6	18.0	60.0	64.6		
HP-No-L	224.3	1.7	4.6	4.1	17.3	60.0	64.6	20.6	17.7	60.0	64.6		
14K>L	288.3	3.9	12.2	5.5	60.0	54.3	78.3	25.6	3.6	60.0	55.3	78.3	
14K>NL	288.3	3.9	12.2	5.5	60.0	53.0	78.3	25.6	3.6	60.0	53.8	78.3	
HP-L	288.3	3.9	12.2	5.5	60.0	53.2	78.3	25.6	3.6	60.0	54.0	78.3	
20K>L	356.6	3.9	5.6	6.1	60.0	30.7	87.5	30.4	60.0	31.9	87.5		
20K>NL	356.6	3.9	5.6	6.1	60.0	30.0	87.5	30.4	60.0	31.1	87.5		

VCS.E Additional UVC. (Above Level 0 cost.): Lots of branches

CLS	0	1	2	3	4	5	6	7	8	9	10	11	12
0	0	1	4	6	9	11	27	87	147	23	39	99	159
1	0	1	4	6	9	11	27	87	147	23	39	99	159
2	0	1	4	7	11	28	88	149	24	41	101	163	163
3	0	1	4	7 ¹	11	27	87	149	24	41	101	163	163
4	0	2	6	10	28	88	153	31	49	109	174	174	174
5	0	2	6	10	28	88	153	31	49	109	174	174	174
6	0	2	6	10	28	88	152	31	49	109	173	173	173
7	0	4	16	22	82	136	214	42	45	105	161	239	239
8	0	4	16	22	82	135	213	42	45	105	159	237	237
9	0	4	16	22	82	135	213	42	45	105	159	238	238
10	0	4	9	16	76	106	194	40	100	132	219	219	219
11	0	4	9	16	76	105	193	40	100	131	218	218	218

Kw Hrs /Yr

KWS.E	0	1	2	3	4	5	6	7	8	9	10	11	12
6K-L	532	502	470	446	422	415	399	359	352	397	382	344	338
6K-NL	552	519	488	462	437	430	413	372	365	412	396	357	350
6K>L	671	654	609	592	580	554	498	490	553	528	476	467	467
6K>NL	695	677	633	614	601	575	517	509	574	548	493	485	485
8K>L	976	938	906	881	814	733	723	826	761	685	675	675	675
8K>NL	1016	969	943	918	848	763	753	859	792	713	703	703	703
HP-No-L	1040	1004	970	941	870	783	777	880	813	732	721	721	721
14K>L	1508	1446	1345	1309	1178	1112	1076	1229	1219	1097	1034	999	999
14K>NL	1566	1493	1388	1352	1216	1153	1116	1264	1251	1126	1067	1033	1033
HP-L	1553	1477	1376	1339	1206	1143	1104	1259	1241	1117	1058	1024	1024
20K>L	2215	2131	2081	2028	1825	1745	1715	1912	1721	1640	1611	1611	1611
20K>NL	2294	2206	2154	2099	1889	1808	1779	1978	1780	1700	1670	1670	1670

Table C.8 Room Air Conditioners Version of LBL-MIM

The Engineering Inputs Module (continued)

Capital cost / unit / 7													
	0	1	2	3	4	5	6	7	8	9	10	11	12
6K-L	22.5	0.1	0.0	0.3	0.4	0.0	10.7	40.0	0.0	0.0	10.7	40.0	0.0
6K-NL	22.5	0.1	0.0	0.3	0.4	0.0	10.7	40.0	0.0	0.0	10.7	40.0	0.0
6K>L	25.0	0.1	0.0	0.4	0.5	11.2	40.0	0.0	0.0	11.4	40.0	0.0	
6K>NL	25.0	0.1	0.0	0.4	0.5	11.2	40.0	0.0	0.0	11.3	40.0	0.0	
8K>L	32.0	0.2	0.0	0.6	11.8	40.0	0.0	0.0	12.3	40.0	0.0		
8K>NL	32.0	0.2	0.0	0.6	11.7	40.0	0.0	0.0	12.0	40.0	0.0		
HP-No-L	32.0	0.2	0.0	0.6	11.5	40.0	0.0	0.0	11.8	40.0	0.0		
14K>L	41.2	0.6	0.0	0.0	40.0	36.2	0.0	0.0	0.5	40.0	36.9	0.0	
14K>NL	41.2	0.6	0.0	0.0	40.0	35.4	0.0	0.0	0.5	40.0	35.9	0.0	
HP-L	41.2	0.6	0.0	0.0	40.0	35.5	0.0	0.0	0.5	40.0	36.0	0.0	
20K>L	51.0	0.6	0.0	0.0	40.0	20.5	0.0	0.0	40.0	21.2	0.0		
20K>NL	51.0	0.6	0.0	0.0	40.0	20.0	0.0	0.0	40.0	20.7	0.0		
CC.E Additional CC. (Above Level 0 cost): Lots of Branches													
CLS	0	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	1	1	12	52	52	1	12	52	52
1	0	0	0	0	1	1	12	52	52	1	12	52	52
2	0	0	0	1	1	12	52	52	1	12	52	52	52
3	0	0	0	1	1	12	52	52	1	12	52	52	52
4	0	0	0	1	13	53	53	1	13	53	53	53	53
5	0	0	0	1	13	53	53	1	13	53	53	53	53
6	0	0	0	1	12	52	52	1	13	53	53	53	53
7	0	1	1	1	41	77	77	1	1	41	78	78	78
8	0	1	1	1	41	76	76	1	1	41	77	77	77
9	0	1	1	1	41	76	76	1	1	41	77	77	77
10	0	1	1	1	41	61	61	1	41	62	62	62	62
11	0	1	1	1	41	61	61	1	41	61	61	61	61
	0	1	2	3	4	5	6	7	8	9	10	11	12
6K-L	0	0	0	1	2	2	22	99	99	2	22	99	99
6K-NL	0	0	0	0	0	0	0	2	2	0	0	2	2
6K>L	0	0	0	1	1	15	64	64	1	15	65	65	65
6K>NL	0	0	0	0	0	1	2	2	0	1	2	2	2
8K>L	0	0	0	2	26	109	109	2	27	110	110	110	110
8K>NL	0	0	0	0	1	2	2	0	1	2	2	2	2
HP-No-L	0	0	0	0	0	2	2	0	0	2	2	2	2
14K>L	0	1	1	1	37	70	70	1	1	38	71	71	71
14K>NL	0	0	0	0	2	3	3	0	0	2	3	3	3
HP-L	0	0	0	0	4	8	8	0	0	4	8	8	8
20K>L	0	0	0	0	20	30	30	0	20	30	30	30	30
20K>NL	0	0	0	0	2	3	3	0	2	3	3	3	3
CC.E.E	0	2	2	4	95	244	316	171	154	207	318	397	397

Table C.9 Room Air Conditioners Version of LBL-MIM

The Standards Level Module

Levl'n prev	LEV.B	lev.N	Eng:	1	11 Emax
-1	0	1	REM:	1	8 Smax
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=1990	0=1998	1	2	3	4	5
6K-L	0.3	1.8	4.0	4.0	9.2	10.9	26.9
6K-NL	0.1	1.3	3.7	3.7	9.2	10.9	26.9
6K>L	0.4	6.3	6.9	6.9	12.3	12.3	28.1
6K>NL	0.3	10.2	10.2	11.9	14.5	14.5	27.4
8K>L	1.5	4.5	4.5	8.9	12.7	12.7	29.4
8K>NL	0.2	3.2	3.2	7.2	10.4	10.4	27.9
HP-No-L	0.2	2.5	2.5	6.7	10.4	10.4	27.7
14K>L	0.8	4.9	4.9	16.7	16.7	21.8	81.6
14K>NL	0.4	4.8	4.8	16.1	16.1	21.6	81.6
HP-L	0.5	5.3	5.3	16.5	16.5	21.9	81.6
20K>L	1.1	7.1	7.1	7.1	7.1	17.2	75.5
20K>NL	0.5	5.5	5.5	5.5	5.5	15.9	75.5

KWS.R	Kw Hrs /Yr						
LEVEL -->	-1=1990	0=1998	1	2	3	4	5
6K-L	525	501	467.73	467.7	421.8	414.6	398.5
6K-NL	548	520	487.86	487.9	436.9	429.5	412.9
6K>L	667	610	600.05	600	577.1	577.1	553
6K>NL	690	615	615.27	604.3	594.8	594.8	574.5
8K>L	967	941	941.08	898.9	875	875	811.6
8K>NL	1011	970	969.78	937.8	918	918	848.1
HP-No-L	1037	1005	1005.2	967	940.8	940.8	870.3
14K>L	1499	1449	1449.1	1342	1342	1308	1178
14K>NL	1558	1496	1495.6	1388	1388	1352	1216
HP-L	1545	1480	1480.3	1374	1374	1338	1206
20K>L	2193	2136	2135.6	2136	2136	2020	1825
20K>NL	2282	2208	2208.2	2208	2208	2097	1889

Table C.9 Room Air Conditioners Version of LBL-MIM

The Standards Level Module (continued)

CC.R							
LEVEL →	-1=1990	0=1998	1	2	3	4	5
6K-L	0.019	0.093	0.1397	0.14	0.88	0.88	11.58
6K-NL	0.012	0.071	0.1005	0.101	0.88	0.88	11.54
6K>L	0.103	1.149	1.1491	1.149	1.921	1.921	12.44
6K>NL	0.038	2.991	2.9906	3.243	3.607	3.607	12.26
8K>L	0.406	0.984	0.9844	1.095	1.635	1.635	13.06
8K>NL	0.025	0.301	0.3012	0.364	0.82	0.82	12.5
HP-No-L	0.024	0.221	0.2205	0.293	0.82	0.82	12.36
14K>L	0.053	0.361	0.3607	0.55	0.55	0.55	40.55
14K>NL	0.058	0.405	0.4052	0.55	0.55	0.55	40.55
HP-L	0.04	0.375	0.3753	0.55	0.55	0.55	40.55
20K>L	0.129	0.257	0.2571	0.257	0.257	0.55	40.55
20K>NL	0.072	0.374	0.3744	0.374	0.374	0.55	40.55
ADD'L CAPITAL COST *7							
	-1=1990	0=1998	1	2	3	4	5
6K-L	0.036	0.18	0.2693	0.269	1.697	1.697	22.32
6K-NL	5e-04	0.003	0.0042	0.004	0.036	0.036	0.478
6K>L	0.127	1.414	1.4143	1.414	2.364	2.364	15.31
6K>NL	0.002	0.124	0.124	0.134	0.149	0.149	0.508
8K>L	0.84	2.035	2.035	2.264	3.381	3.381	26.99
8K>NL	0.001	0.012	0.0125	0.015	0.034	0.034	0.518
HP-No-L	8e-04	0.008	0.0077	0.01	0.029	0.029	0.431
14K>L	0.048	0.331	0.3308	0.504	0.504	0.504	37.19
14K>NL	0.002	0.017	0.0168	0.023	0.023	0.023	1.681
HP-L	0.004	0.038	0.0381	0.056	0.056	0.056	4.112
20K>L	0.062	0.125	0.1246	0.125	0.125	0.267	19.66
20K>NL	0.003	0.016	0.0155	0.016	0.016	0.023	1.681
CCEE.R							
LEVEL	-1=1990	0=1998	1	2	3	4	5
Cumltv CC	0	0					
	1	4	4	5	8	9	131
	1990	1996	NEW96	1990	1996	NEW96	
	VC87	VCB	VCN	KW87	KWB	KWN	
6K-L	0.288	1.795	3.9906	525	501.3	467.7	
6K-NL	0.085	1.311	3.7136	548.1	520.4	487.9	
6K>L	0.416	6.254	6.9193	666.6	610.1	600	
6K>NL	0.295	10.15	10.15	689.7	615.3	615.3	
8K>L	1.455	4.463	4.4625	967.5	941.1	941.1	
8K>NL	0.176	3.196	3.1963	1011	969.8	969.8	
HP-No-L	0.171	2.53	2.5297	1037	1005	1005	
14K>L	0.78	4.938	4.9382	1499	1449	1449	
14K>NL	0.408	4.795	4.7951	1558	1496	1496	
HP-L	0.523	5.336	5.3359	1545	1480	1480	
20K>L	1.078	7.09	7.0905	2193	2136	2136	
20K>NL	0.507	5.533	5.5329	2282	2208	2208	

Table C.9 Room Air Conditioners Version of LBL-MIM

The Standards Level Module (continued)

	1990	1996	NEW96	Weighted	Base Case	New Sds	
	CPC87	CPCB	CPCN	Op Cost	Weighted	Weighted	
					d P	d P	
6K-L	0.019	0.093	0.1397	145.2	0.417	1.024	
6K-NL	0.012	0.071	0.1005	3.259	0.007	0.022	
6K>L	0.103	1.149	1.1491	117.7	1.031	1.148	
6K>NL	0.038	2.991	2.9906	4.101	0.059	0.059	
8K>L	0.406	0.984	0.9844	286.9	0.892	0.892	
8K>NL	0.025	0.301	0.3012	6.01	0.018	0.018	
HP-No-L	0.024	0.221	0.2205	5.183	0.012	0.012	
14K>L	0.053	0.361	0.3607	197.1	0.547	0.547	
14K>NL	0.058	0.405	0.4052	9.264	0.026	0.026	
HP-L	0.04	0.375	0.3753	22.48	0.07	0.07	dVC.B.CV
20K>L	0.129	0.257	0.2571	152.5	0.418	0.418	25.00%
20K>NL	0.072	0.374	0.3744	13.57	0.03	0.03	
			Wgt Fuel Cost: F	79.76	3.526	4.26	
					dVC.B0	dVC.N0	
				---OUTPUT---			
	CC.87	CCB	CCN	CC.B0	CC.N0		
	1.13	4.30	4.39	3.18	3.27		

Table C.10 Room Air Conditioners Version of LBL-MIM

The Costs, Sales, and Revenue Module

			bb	-58
			aa	961
Ratio of highest to lowest markup:	ratio.0	2.00	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 (1990)

	Indst	Relatv			Firm			
	Ship.	Ship.	Ship.	Price	Rev.		UVC.1	Weighted
		Q%	Q.1	P.1/Range	R.1	m.1		"UVC
6K-L	1.38	0.28	0.28	215.34	59.31	1.28	167.67	46.37
6K-NL	0.03	0.01	0.01	215.34	1.28	1.28	167.67	1.00
6K>L	0.88	0.18	0.18	240.13	42.22	1.31	183.29	32.36
6K>NL	0.03	0.01	0.01	240.13	1.42	1.31	183.29	1.09
8K>L	1.48	0.30	0.30	307.32	90.76	1.38	222.69	66.04
8K>NL	0.03	0.01	0.01	307.32	1.82	1.38	222.69	1.32
HP-No-L	0.02	0.01	0.00	307.32	1.53	1.38	222.69	1.11
14K>L	0.66	0.13	0.13	394.96	51.74	1.47	268.46	35.32
14K>NL	0.03	0.01	0.01	394.96	2.34	1.47	268.46	1.60
HP-L	0.07	0.01	0.01	394.96	5.72	1.47	268.46	3.90
20K>L	0.35	0.07	0.07	488.58	33.84	1.57	311.48	21.66
20K>NL	0.03	0.01	0.01	488.58	2.89	1.57	311.48	1.85
TOTAL S	4.98	20.00%	1.00	\$296	294.87	1.39	20.00%	\$213.62
	"TS.0	"Q.CV	Q.0	P.0	R		"P.CV	UVC

BASE CASE (1996)

	Rule-of-		Rule-of-		Op Cost		Weightd	
	Thb d P		Thb Price	Pi.B	Ratio	OpCst-R	Qi.B	Ri.B
6K-L	2.02	60.10	1	\$217.2	0.95	0.26	0.2765	60.05
6K-NL	1.64	1.29	0	\$216.9	0.95	0.01	0.0059	1.29
6K>L	8.88	43.96	14	\$245.3	0.92	0.16	0.1765	43.29
6K>NL	16.37	1.52	2	\$243.7	0.89	0.01	0.0059	1.45
8K>L	4.86	92.56	7	\$311.1	0.97	0.29	0.2965	92.23
8K>NL	4.51	1.85	0	\$310.9	0.96	0.01	0.0059	1.85
HP-No-L	3.50	1.55	0	\$310.2	0.97	0.00	0.0050	1.55
14K>L	6.52	52.81	6	\$399.5	0.97	0.13	0.1315	52.54
14K>NL	6.91	2.39	0	\$399.6	0.96	0.01	0.0059	2.38
HP-L	7.52	5.85	1	\$399.8	0.96	0.01	0.0145	5.81
20K>L	9.61	34.64	6	\$493.8	0.97	0.07	0.0695	34.34
20K>NL	8.31	2.95	0	\$493.6	0.97	0.01	0.0059	2.93
	0.05	301.49	37	299.7	299.70	-0.04	0.9999	299.70
	Alpha.B	Sum P (2)	Sum (3)	"P.B	Sum(Ri) check+R.B.	OC%.B0	"Q.B	"R.B

Table C.10 Room Air Conditioners Version of LBL-MIM

The Cost, Sales, and Revenue Module (continued)

NEW STANDARDS CASE (1996)								
	Rule-of- Thb d P	Rule-of- Thb Price		Pi.B	% Chng Op Cost	Weightd OpCst-R	Qi.N	Ri.N
6K-L	4.90	61.09	7	\$219.1	0.89	0.25	0.2774	60.77
6K-NL	4.76	1.31	0	\$219.0	0.89	0.01	0.0060	1.31
6K>L	9.76	44.25	17	\$245.2	0.90	0.16	0.1771	43.43
6K>NL	16.41	1.53	2	\$243.4	0.89	0.01	0.0060	1.45
8K>L	4.87	92.87	7	\$311.0	0.97	0.29	0.2975	92.5204
8K>NL	4.51	1.86	0	\$310.8	0.96	0.01	0.0060	1.85
HP-No-L	3.50	1.56	0	\$310.2	0.97	0.00	0.0050	1.56
14K>L	6.53	52.98	6	\$399.4	0.97	0.13	0.1320	52.70
14K>NL	6.92	2.40	0	\$399.5	0.96	0.01	0.0060	2.38
HP-L	7.53	5.87	1	\$399.7	0.96	0.01	0.0146	5.83
20K>L	9.61	34.75	6	\$493.7	0.97	0.07	0.0698	34.44
20K>NL	8.31	2.96	0	\$493.5	0.97	0.01	0.0060	2.94
TOTAL	0.05	303.44	46	300.3	301.18	-0.06	1.0031	301.18
	Alpha.N	Sum P (2)	Sum (3)	"P.N	Sum(Ri)	OC%.N0	"Q.N	"R.N
check=R.N								

Table C.11 Room Air Conditioners Version of LBL-MIM

The Financial Module

INPUT	NAME	VALUE	NAME	C.V. or Control Factor
RATES of COST				
After Tax Equity Cost of Capital	BCC.0	9.07	BCC.CV	10%
Interest Rate on Debt	LD	2.50%	LCV	100%
Interest Lost on Cash	ICash.0	0.01	ICASH.CV	100%
Rate of Depreciation	Dep.0	0.18		
Tax Rate	T.0	34.00%	T.CV	20%
ASSETS and COSTS as a PERCENT of REVENUE				
Cash	C.R.0	23%	C.R.CV	100.00%
Inventory & Receivables	IR.R.0	64%	IR.R.CV	27.19%
Depreciable Assets	DA.R.0	22%	DA.R.CV	36.89%
G & A	G&A.0	17%	G&A.CV	40.00%
Engineering	Eag	1.20%		
FIXED AND VARIABLE COST SPLIT				
Fixed Part of All Costs & Depr Assets	FDA.0	11.50%	FCA.CV	50.00%
Fixed Part of 1-X Capital Cost	FIX.0	9.68%	FIX.CV	60.00%
OTHER				
Economic Profit	EP.0	1.84%	EP.CV	1.00%
Debt to Equity ratio	DER.0	62.67%	DER.CV	43.36%
Markup on typical model	*mid	38.00%		
Ratio of highest to lowest markup	*ratio	200.00%		
OUTPUT				
Depreciation	DRR	4.1%		
G&A to Overhead Ratio	G:O	93.3%		
Engineering to Overhead Ratio	E:O	6.7%		
Debt Ratio	DR	38.5%		
Equity Ratio	ER	61.5%		
Pre-Tax Equity Cost of Capital*	PECC	10.3%		
Weighted Average Cost of Capital	WACC	7.3%		
After Tax WACC	ATWACC	4.8%		
ROE = ECC + EP & EP = ROE - ECC				
Return on Equity (calculated)	ROE	8.64%		
	*ROE.00	8.64%		

Table C.12 Room Air Conditioners Version of LBL-MIM

The One-Time Cost Amortization Module

INPUTS				
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	4.70%	
Weighted CC Lead-Time Factors	0.00	0.28	0.54	0.26
Cumulative CC Lead-Time Factors		LTC.0	1.078	
$\exp(-ATR \cdot TL)$		EMRT	0.754	
$\exp(-ATR \cdot L)$		EMRL	0.686	
Rate of tax benefit	3.30	BN	0.057	
Remaining tax life		RTL	5.00	years
Tax Benefit Rate: $(1 - \%NC) \cdot BN$		BEN	0.028	
Discount factor: $@\exp(-ATR \cdot (L - (TL - RTL)))$		DIS	0.72	
Loss of tax benefit on portion of existing capital with remaining tax life		LEC1	0.126	
Loss of tax benefit on discounted existing capital expenditure in the future		LEC2	0.107	
LEVELIZED CC			GROSS CC	TAX EFF
Initial Cost			1.000	
Tax Benefit of Straight-Line Depreciation				0.296
Savings from not replacing existing Capital later			-0.360	
Loss of Tax Benefit from existing Capital				-0.233
Present Value of CC:			0.640	0.063
Adjusted for Capital Lead Time			0.690	0.068
Levelized Tax Benefit: 1-X dep. of existing Cap.				0.004
LEVELIZED CC FACTOR		OCLF	0.103	0.014
AVERAGE ASSET FACTOR				
Asset Factor for Any New Cap. or Asset		AFB	0.562	
Average Asset Factor for Add-on Capital		AAF	0.281	
INPUT				
NEW CAP. COST: 1990-96 (\$000)	CC.B0	3.18		
1996 CHANGE	CC.N	3.27		
COEFFICIENTS OF VARIATION	OCL.CV	0.20		
OUTPUT				
	BASE CASE 1996		NEW STNDS 1996	
Levelized 1-X CC: Gross	LCC.B	0.33	LCC.N	0.34
Levelized 1-X CC: Tax Effects	LCC.TB	0.043961	LCC.TN	0.04521
Levelized 1-X CC: Net	LCC.NB	0.28	LCC.NN	0.29
Levelized 1-X Assets	LA.B	0.89	LA.N	0.92

Table C.13 Room Air Conditioners Version of LBL-MIM

The Long-Run Model Module

1990 CASE		A.F	A.Q	A:R	A
Assets -->		0.026	1.072	1.098	324
Costs except taxes		TC.F	TC.Q	TC:R	TC
and equity -->		0.115	0.797	0.912	269
		EC.F	EC.Q	EC:R	EC
Economic costs -->		0.077	0.571	0.988	291
	Economic Income			EI:R	0.0124
	Markup (mu - 1)			mu1	0.1567
	Price Leader's elasticity of demand:				-7.4
BASE 1996		A.BF	A.BQ		A.B
Assets		7.60	317.53		325.98
		TC.BF	TC.BQ		TC.B
Costs except taxes		33.90	239.40		273
		EC.BF	EC.BQ		EC.B
Economic costs		22.73	171.57		295
NEW 1996		A.NF	A.NQ		A.N
Assets		7.60	317.53		327.03
		TC.NF	TC.NQ		TC.N
Costs except taxes		33.90	240.14		275
		EC.NF	EC.NQ		EC.N
Economic costs		22.73	172.07		296
Assets	-----1990-----	---BASE 1996---	---NEW 1996---		
Shipments	*Q 1.00	Q.B 1.00	Q.N	1.00	
Price	*P \$296.08	P.B \$299.75	P.N	\$300.25	
Revenue	*R 294.87	R.B 299.70	R.N	301.18	
Unit Var. Cost	*UVC \$213.62	UVC.B \$217.15	UVC.N	\$217.89	
V. Cost Goods Sold	VCGS 212.75	VCGS.B 217.12	VCGS.N	218.56	
1X tax benefit		X1T.B 0.04	X1T.N	0.05	
Pre-tax cost	PTC 268.81	PTC.B 273.60	PTC.N	275.12	
Taxes	TAX 8.86	TAX.B 8.94	TAX.N	8.93	
Net Income	NI 17.20	NI.B 17.16	NI.N	17.13	
Economic Income	EI 3.66	EI.B 3.54	EI.N	3.46	
Equity	EQ 199.07	EQ.B 200.39	EQ.N	201.04	
Retrn on Equity	*ROE 8.64%	ROE.B 8.56%	ROE.N	8.52%	
ACCOUNTING PAGE CALCULATIONS					
	-----1990-----	---BASE 1996---	---NEW 1996---		
Interest not1X	IC 2.72	IC.B 2.09	IC.N	2.09	
Pre-intrst cst	PIC 266.09	PIC.B 271.58	PIC.N	273.10	
1X depreciation		X1D.B 0.40	X1D.N	0.41	
1X interest		X1I.B 0.01	X1I.N	0.01	
1X equity cost		X1E.B 0.04	X1E.N	0.04	

Table C.14 Room Air Conditioners Version of LBL-MIM

The Short-Run Model Module

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	301.40	"P.N	\$300.25	
UVC.S	\$217.89	"Q.N		1.00
VCGS.S	218.48			
TC.S	274.70		ap	bp
TAX.S	9.12	P=a+bQ	253.11	47.33
PTC.S	275.12	1.00	cq	dq
NLS	17.16	Q=c+dP	1.34	0.00
A.S	327.03			
EQ.S	201.04	P.S	300.57	
ROE.S	8.54%	Q.S		1.00
		Check P	\$300.39	
		Check Q		1.0026

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.15 Room Air Conditioners Version of LBL-MIM

The Charts Module

CHARTS OF SENSITIVITY AND PROFIT FOR ROOM AIR CONDITIONERS

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

Scenario = Primary

Control Variables			Possible Standards Levels				
Name	Value	Changed	1	2	3	4	5
IPE	-0.330	-0.759	0.05%	0.06%	0.10%	0.10%	-0.66%
RD	48.80%	112.20%	0.03%	0.08%	0.15%	0.18%	0.40%
ECC	0.068	0.075	0.00%	0.00%	0.00%	0.00%	-0.08%
EP	0.018	0.028	-0.01%	-0.01%	-0.02%	-0.02%	-0.04%
FCA	0.115	0.184	-0.02%	-0.03%	-0.05%	-0.05%	0.22%
F1X	0.097	0.168	-0.01%	-0.01%	-0.03%	-0.03%	-1.09%
CC.N	3.266	3.981	0.00%	0.00%	0.00%	0.00%	-0.30%
dVC.N	4.265	5.720	0.03%	0.04%	0.06%	0.08%	0.12%
ro.N	0.000	0.300	0.04%	0.05%	0.08%	0.07%	-0.35%
SRPR	0.157	0.594	0.00	0.00	0.00	0.00	0.00

Change in Long-Run ROE from 1996 NAECA Base Case by Engineering and Standards Levels

Scenario = Primary

Level	Engin	Standrds
1	-0.06%	-0.04%
2	-0.15%	-0.06%
3	-0.19%	-0.12%
4	-0.21%	-0.11%
5	-0.25%	-1.22%
6	-0.16%	0.06%
7	-3.28%	-0.01
8	-1.56%	-0.02
9		
10		
11		
12		

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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 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 and ovens, the test load is made from aluminum and black anodized. The size of the load depends on the application. For microwave ovens, the test load is a fixed amount of water in a suitable container. The DOE has recently proposed that the International Electrotechnical Commission (IEC) test procedure for microwave ovens be adopted (1). 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 DOE test procedure provides values for the annual useful cooking energy output. When the test was developed in the mid-1970s, these 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. New usage values have been developed from metered data and conditional demand analysis performed by gas and electric utilities. These values will be presented later in a discussion of energy use data for each of the different cooking appliances (i.e., cooktops, ovens, microwave ovens).

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:

$$P = 4,187 \times \Delta T/t$$

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.

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

NAECA does not provide a basis for selecting product classes as 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 after further review, the number of product classes being proposed for analysis have been significantly reduced. This is in part due to the decision to drop from consideration product classes for ranges (combination cooktop and oven appliance). The classes and efficiency standards (if any) 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 standards for ranges. 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
Electric Ovens
9. Standard Oven with or without a Catalytic Line
10. Self-Clean Oven
Gas Ovens
11. Standard Oven with or without a Catalytic Line
12. Self-Clean Oven
Microwave Ovens
13. 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. Although solid disk elements are easier to clean than open (coil) elements, they are less efficient and a lower standard is established for them. 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. Though separate classes are being established for grill and griddle cooktops, an engineering analysis will not be performed for them. They account for about 3.5% of all electric cooktops sold in the U.S. The primary reason for this 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 (2). Since cooktops equipped without electrical cords have the ability 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 (3). 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 energy for cleaning. The continuous-cleaning system is a catalytic process where, 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, where 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 than 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) will here be analyzed as design options. 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 are established. 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 (4). The DOE test procedure for microwave ovens does not measure the energy use of the browning element; therefore, there is no basis to establish separate classes for these two kinds of microwave ovens.

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

1.3 COOKTOPS

1.3.1 Design Options for Cooktops

The design options for cooktops are listed in Table 1.2. 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 1.2 Design Options for Cooktops

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, a 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. Though 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.

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 Laboratory (LBL) (5), and an energy-efficient electrical product knowledge base prepared by ORTECH International for the Canadian Electrical Association (6). Averaging the data from these sources results in an efficiency increase of just over 4%.

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 using 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 (7), and a 1980 U.S. Department of Energy Engineering Analysis for residential appliances (8). 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 countertop 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 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 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 (9). 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 accidentally 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 against 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 NIST, developed a proposed method of measuring the energy consumption of induction cooktops (10). 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 (11). An absolute efficiency of 80 to 82% 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. 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 (12).

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 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 electric coil cooktops.

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 (13) in support of developing energy efficiency standards for a variety of consumer products including cooktops and ovens. Although the document does not specify how the burner should be redesigned and shrouded, a percentage point efficiency increase of 3 is given for incorporating this improvement into gas burners.

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 effected 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 that are 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 accidentally extinguished. Unsupervised modules use a sensor located at the burner to sense when the flame has been accidentally 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 accidentally 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 igniter 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 (14) 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 4.8% 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 only an efficiency increase of 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 countertop 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 a 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.

The Gas Research Institute (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 used: manufacturers' data provided by AHAM, manufacturers' data provided by the Canadian Standards Association (CSA) (15), manufacturers' data obtained independently of any trade organization, a costing analysis of design options for residential appliances prepared by ADM Associates for Lawrence Berkeley Laboratory (LBL) (16), an energy-efficient electrical product knowledge base prepared by ORTECH International for the Canadian Electrical Association (17), a 1980 U.S. Department of Energy Engineering Analysis for residential appliances (18), and an appliance knowledge base prepared by Rocky Mountain Institute (19). Averaging the data provided from these sources resulted in a baseline cooking efficiency of 77.2% for a four-element electric coil cooktop. The cooktop was assumed to consist of two 6" elements and two 8" elements. The electrical input ratings of the 6" and 8" 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" elements and two 8" 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. Averaging the data from the sources that provided smooth cooktop data resulted in a baseline cooking efficiency of 71.3% for a four-element electric smooth cooktop. The electrical input ratings of the 6" and 8" 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 and 2 are provided by the DOE test procedure to calculate a gas cooktop's cooking energy consumption and energy factor. Eq. 3 (Eqs. 1 and 2 combined) demonstrates the relationship between a gas cooktop's efficiency and energy factor.

$$E_{CC} = O_{CT} / \text{Eff}_{CT} \quad (1)$$

where:

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

$$R_{CT} = O_{CT} / E_{CA} \quad (2)$$

where:

R_{CT} = Cooktop Energy Factor,
 O_{CT} = Annual Useful Cooking Energy Output,
 E_{CA} = Total Annual Energy Consumption of Cooktop = $E_{CC} + E_{PC}$ and
 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. 2 is also used to determine the energy factor of electric cooktops.

$$R_{CT} = O_{CT} / (E_{CC} + E_{PC}) = O_{CT} / [(O_{CT} / \text{Eff}_{CT}) + E_{PC}] \quad (3)$$

As evidenced from Eq. 2, 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. 2, the energy factor is dependent upon what value is used for the annual useful cooking energy output (O_{CT}). The DOE test procedure establishes an annual useful cooking energy output value of 277.7 kWh/year and 947,500 Btus/year for electric and gas cooktops, respectively. The DOE test procedure for cooking appliances, finalized in the late 1970s, established values for the useful cooking energy output. Manufacturers have contended that new values for the useful cooking energy output should be determined because cooking habits have drastically changed since the time the DOE values were established. Taking manufacturers' concerns into account, an analysis was performed to determine how the DOE values should be amended. This analysis used a variety of electric and gas utility reports to determine an "adjusted" cooking energy output value. These utility reports used either conditional demand analyses or metered data to establish the energy use of cooking appliances. For a more detailed description of the analysis to determine an "adjusted" cooking energy output value, refer to Section A.1 in Appendix A of this volume. The "adjusted" annual useful cooking energy output values that were determined for electric and gas cooktops were 209.4 kWh/year and 732,500 Btus/year, respectively. Table 1.3 presents the baseline energy factors and cooking efficiencies for the three cooktop product classes. As evidenced in Table 1.3, electric cooktop energy factors based on DOE and "adjusted" cooking output values are identical. Since the energy factor is equal to the cooking efficiency, the useful cooking energy output value does not have any bearing on the energy factor.

Table 1.3 Baseline Cooktop Energy Factors and Cooking Efficiencies

Product Class	Energy Factor		Efficiency
	DOE	Adjusted	DOE
Electric Coil	77.2%	77.2%	77.2%
Electric Smooth	71.3%	71.3%	71.3%
Gas	21.4%	18.8%	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 percentage increase or an absolute percentage point increase. 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 1.4 and 1.5 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. Two annual energy consumptions are presented: one is based on the DOE value for the annual useful cooking energy output (277.7 kWh/yr) and the other is based on the "adjusted" value (209.4 kWh/yr). Referring back to Eq. 1, 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 1.4 and 1.5 are the total manufacturing costs for each design option. These costs will be explained in the following section (Cost-Efficiency Data).

Table 1.4 Cost-Efficiency Table for Electric Coil Cooktops

Standard Level	Design No.	Design Option		Mfg. Cost 1990 \$	Eff %	EF %	DOE <i>E_{CA}</i> kWh	Adjusted <i>E_{CA}</i> kWh
1	0	Baseline	(1)	69.06	77.2	77.2	359.5	271.1
2	1	0 + Impr Contact Conductance	(2)	71.34	80.5	80.5	345.1	260.2
3,4,5	2	1 + Reflective Surfaces	(3)	74.37	81.3	81.3	341.7	257.7

Notes:

- 1 Baseline: Cooktop Cooking Eff. = 77.2%; two 6" (1250 watt) and two 8" (2100 watt) elements
- 2 Improved Contact Conductance: Cooking Efficiency increase = 4.3%
- 3 Reflective Surfaces: Cooking Efficiency increase = 1.0%

Table 1.5 Cost-Efficiency Table for Electric Smooth Cooktops

Standard Level	Design No.	Design Option		Mfg Cost 1990 \$	Eff %	EF %	DOE <i>E_{CA}</i> kWh	Adjusted <i>E_{CA}</i> kWh
1,2,3	0	Baseline	(1)	89.14	71.3	71.3	389.5	293.7
4	1	0 + Halogen Lamp Element	(2)	255.12	72.4	72.4	383.6	289.2
5	2	0 + Induction Element	(3)	370.74	81.0	81.0	342.8	258.5
-	3	0 + Radiant Element	(4)	137.28	68.7	68.7	404.1	304.7

Notes:

- 1 Baseline: Cooktop Cooking Eff. = 71.3%; two 6" (1500 watt) and two 8" (2000 watt) solid disk elements
- 2 Halogen: Cooking Eff. increase = 1.5%; two small (1200 watt) and two large (1800 watt) circular lamps
- 3 Induction: Cooktop Cooking Eff. = 81.0%
- 4 Radiant: Cooking Eff. decrease = 3.6%; two small (1200 watt) and two large (1700 watt) radiant elements

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. 2, 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. 4.

$$E_{PC} = P * A \quad (4)$$

where: E_{PC} = Annual Energy Consumption of any Continuously Burning Gas Pilots
 P = Pilot Light Input Rate (Btu/h)
 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/h. This represents an annual pilot energy consumption of 2050 kBtus.

The results of the energy efficiency analysis for gas cooktops is presented in Table 1.6. 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 Table 1.6, two values are presented for each of the following quantities: the annual cooking energy consumption, the total annual energy consumption, and the energy factor. One set of values is based on using the DOE value for the annual useful cooking energy output (947,500 Btus/year) while the other set is based on using the "adjusted" value (732,500 Btus/year). Referring back to Eq. 1, 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. 4). Referring back to Eq. 2, the energy factor is calculated by dividing the annual useful cooking energy output by the total annual energy consumption. Also included in Table 1.6 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 1.4 through 1.6 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 (Table 1.5), none of the design options listed (i.e., induction, halogen, and radiant elements) have a low manufacturing cost. Due to the associated high costs of the design options, the probability that any of them will be cost-effective is low.

Table 1.6 Cost-Efficiency Table for Gas Cooktops

Std. Level	Design No.	Design Option		Mfg. Cost 1990 \$	Eff %	E _{PC} kBtu	DOE			Adjusted		
							E _{CC} kBtu	E _{CA} kBtu	EF %	E _{CC} kBtu	E _{CA} kBtu	EF %
-	0	Baseline	(1)	89.09	39.9	2050	2376	4426	21.4	1837	3887	18.8
1	1	0 + Reduce Burner Excess Air	(2)	89.87	42.9	2050	2210	4260	22.2	1708	3758	19.5
2	2	1 + Electronic Ignition	(3)	104.66	42.9	0	2210	2210	42.9	1708	1708	42.9
-	3	2 + Sealed Burners	(4)	124.66	45.0	0	2107	2107	45.0	1629	1629	45.0
3,4,5	4	3 + Reflective Surfaces	(5)	130.80	45.0	0	2105	2105	45.0	1627	1627	45.0
-	5	4 + Thermostatic Burners	(6)	147.73	45.0	0	2105	2105	45.0	1627	1627	45.0

Notes:

- 1 Baseline: Cooktop Cooking Eff. = 39.9%; four conventional 9000 Btu/h burners, two 117 Btu/h standing pilots
- 2 Reduce Burner Excess Air: Cooking Efficiency increase = 3 percentage points
- 3 Electronic Ignition: Eliminate Standing Pilots, Cooking Efficiency increase = 0.0%
- 4 Sealed Burners: Cooking Efficiency increase = 4.8%
- 5 Reflective Surfaces: Cooking Efficiency increase = 0.1%
- 6 Thermostatically Controlled Burners: Cooking Efficiency increase = 0.0%

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. The associated minimum technologically feasible energy use is based upon the value chosen for the annual useful cooking energy output. If the value listed in the DOE test procedure is used, the minimum energy use is 341.7 kWh/year. A minimum energy use of 257.7 kWh/year is calculated if the "adjusted" value for the useful cooking energy output is used. For electric smooth cooktops, the "max tech" design is a cooktop consisting of four induction elements. Its minimum technologically feasible energy use is 342.8 kWh/year, if the DOE value for the useful cooking energy output is used and 258.5 kWh/year if the "adjusted" value is used. For gas cooktops, the "max tech" design consists of four sealed burners, which incorporate reflective surfaces and electronic ignition. In addition, the cooktop is designed to reduce the amount of excess air at the burners. Its minimum technologically feasible energy use is 2105 kBtus/year if the DOE value for the useful cooking energy output is used and 1627 kBtus/year if the "adjusted" value is used.

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 the net present value 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 (20). 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. At a 6% discount rate, the net present value of the maintenance cost associated with electronic ignition devices was calculated to be \$81 (in 1990 dollars). For more details regarding the development of this maintenance cost, please refer to Appendix D in Volume A of this Technical Support Document (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 both electric and gas cooktops, design options were assumed not to increase the installation cost of the cooktop.

The cost and efficiency data were combined and are presented in Tables 1.4 to 1.6. These tables were presented in the previous section on Energy-Use Data (Section 1.3.2). Appendix A, Section A.2 of this volume 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 (21) 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 Lawrence Berkeley Laboratory (22) 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 (23) was used to estimate the cost of induction elements for electric smooth cooktops. And finally, a research organization familiar with the development of cooking appliances provided estimates of the cost to incorporate sealed burners into gas cooktops.

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. In addition, the gas cooktop is designed to reduce the amount of excess air at the burners. 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 1.4 through 1.6 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 A of the Technical Support Document 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 1.7. 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 1.7 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.

To determine how much energy is lost by oven door openings, the following assumptions are made:

1. When the oven door is opened, all of the oven air is replaced by ambient air.
2. Both the specific heat and the density of air are assumed to remain constant over the range of temperatures in the DOE test procedure (ambient air temperature = 77 °F and oven air temperature = 325 °F).

The additional amount of energy required to heat the test block as a result of opening the door is calculated by using the following formula:

$$\text{Energy Lost} = \text{Door Openings} * V * \rho * C_p * (T_o - T_a)$$

where:

- V = volume of the oven (3.9 cubic feet),
- ρ = density of air (0.074 lb/cu ft.),
- C_p = specific heat of air (0.24 Btu/lb.-°F),
- T_o = oven temperature (325 °F), and
- T_a = ambient temperature (77 °F).

Substituting these typical values in the formula above results in an energy loss of 17.2 Btus per oven door opening.

Using data from an energy-efficient electrical product knowledge base prepared by ORTECH International for the Canadian Electrical Association (24), the cooking efficiency increase from eliminating the oven door window is estimated at 4%. In order to obtain a "rough" estimate of how many Btus this efficiency increase represents, the cooking performance of a typical non-self-cleaning gas oven (with pilot ignition) is analyzed. First, the annual cooking energy consumption is calculated. It is determined by dividing the annual useful cooking energy output of a conventional gas oven (DOE value of 160.7 kBtus) by its efficiency (typically 6.0%). Using these values, the annual cooking energy consumption is 2678 kBtus. To determine the cooking energy use per cycle, divide the annual energy use by the number of times an oven is used per year. The number of times an oven is used per year is established by using DOE test procedure values. Dividing the annual useful cooking output of 160.7 kBtus by the amount of energy absorbed by the aluminum test block ($234\text{ °F} * 0.23\text{ Btu/lb.-°F} * 8.5\text{ lb} = 457.5\text{ Btus}$) gives an estimate of approximately 351 cycles per year. Based on 351 cycles per year, the cooking energy use per cycle is 7630 Btus. Thus, the amount of energy saved by eliminating the door window is approximately 305 Btus per cycle ($7630\text{ Btus} * 4\%$).

Comparing the above results, it would take approximately 17 door openings during the course of a cooking cycle to offset the energy saved by eliminating the door window. This result indicates that eliminating the door window is a viable way of improving the efficiency.

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/cu ft) fiberglass insulation in the cabinet walls and door, while most self-cleaning ovens use 2 inches of high density (1.90 lb/cu ft) 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/cu ft). 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/cu ft): 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 Laboratory (25), an energy-efficient electrical product knowledge base prepared by ORTECH International for the Canadian Electrical Association (26), and a 1980 U.S. Department of Energy Engineering Analysis for residential appliances (27). Averaging the data from these sources results in an efficiency increase of 4.9% for standard gas ovens and a 5.5% increase for standard electric ovens.

Two sources of data were available for establishing the increase in efficiency due to adding more insulation (2 to 4 inches): manufacturers' data provided by the Association of Home Appliance Manufacturers (AHAM) and a 1980 U.S. Department of Energy Engineering Analysis for residential appliances (28). Averaging this data results in an percentage point increase of approximately 1.4.

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. Averaging the manufacturers' data with data obtained from a costing analysis of design options for residential appliances prepared by ADM Associates for Lawrence Berkeley Laboratory (29) results in a percentage point increase of approximately 0.6.

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 it 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.

According to manufacturers' data provided by AHAM, a percentage point increase of 0.5 is expected from using reflective surfaces. No data were found or provided by other sources on this design option.

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 following sources were used to establish the efficiency increase from reducing the thermal mass: 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 Laboratory (30), and an energy-efficient electrical product knowledge base prepared by ORTECH International for the Canadian Electrical Association (31). Averaging the data from these sources results in an efficiency increase of approximately 5.0% for standard and self-cleaning electric ovens and self-cleaning gas ovens and 3.9% for standard gas ovens.

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 the Gas Research Institute (GRI) has sponsored the development of two new types of gas ovens that incorporate forced convection cooking. Both oven types, one an advanced countertop 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 Arthur D. Little, Inc. Of the two oven types, development of the countertop oven is farther along. Test results indicate that countertop oven cooking times are as fast as those found in microwave ovens (32).

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 (33)) were used to establish the efficiency increase due to forced convection. Averaging these estimates results in an efficiency increase of 23% for ovens using forced convection cooking. 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 accidentally 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 0.8 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 0.7 and 0.5 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 (34) were used to estimate the efficiency increase from improving the door seals. The data indicated that approximately a 7% increase in efficiency was possible for standard electric ovens and both standard and self-cleaning gas ovens.

Steam Cooking

A German manufacturer has developed an oven that incorporates steam cooking into a electric convection oven (35). 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 countertop oven, while the other is an advanced full size-oven with pyrolytic self-cleaning. Of these two oven types, development of the countertop oven is farther along. Test results indicate that countertop oven cooking times are as fast as those found in microwave ovens (36).

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 accidentally 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 3.2 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 3.2 amps, the ignitor must continually draw power (approximately 380 watts) to keep the burner ignited. 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.

In the analysis of ignition systems for gas ovens, "glo" type systems were the only type of pilotless ignition systems 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 (37). 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 control 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.

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 Lawrence Berkeley Laboratory (38), an energy efficient-electrical product knowledge base prepared by ORTECH International for the Canadian Electrical Association (39), and a 1980 U.S. Department of Energy Engineering Analysis for residential appliances (40). Averaging 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 cubic feet with 2" of fiberglass insulation (density of 1.09 lb/cu ft) in the cabinet walls and door.

For self-cleaning electric ovens, the volume of the oven cavity was also assumed to be 3.9 cubic feet. The cabinet walls and doors were assumed to contain 2" of 1.90 lb/cu ft 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 (41). Averaging the data provided by these sources resulted in a baseline cooking efficiency of 13.90% for self-cleaning electric ovens. The self-cleaning energy consumption, as measured according to the DOE test procedure, and the power consumption of the clock were determined to be 5286 watt-hours 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/hour. The volume of the oven cavity was assumed to be 3.9 cubic feet with 2" of fiberglass insulation (density of 1.09 lb/cu ft) 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 (42). 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, as measured according to the DOE test procedure, and the power consumption of the clock were determined to be 43,158 Btus 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. 5. The energy factor is a function of the annual useful cooking energy output and the total annual energy consumption.

$$R_o = O_o / E_{AO} \quad (5)$$

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. 6.

$$E_{AO} = E_{CO} + E_{SC} + E_{CL} \quad (6)$$

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. 7.

$$E_{CO} = O_O / \text{Eff} \quad (7)$$

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. 8 and 9, respectively.

$$E_{SC} = E_S * S_e * C \quad (8)$$

where:

E_S = energy consumption measured during the self-cleaning operation (watt-hours),
 S_e = 11, average number of times a self-cleaning operation of an electric oven is used per year, and
 C = 0.001 kW/W, conversion factor of watts to kilowatts.

$$E_{CL} = P_{CL} * H_K \quad (9)$$

where:

P_{CL} = power rating of clock (watts), and
 H_K = 8.76, thousands of 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. 10.

$$R_O = O_O / [E_{AOG} + (E_{AOE} * H_e)] \quad (10)$$

where:

- R_O = energy factor,
- O_O = annual useful cooking energy output (Btus),
- E_{AOG} = total annual gas energy consumption (Btus),
- E_{AOE} = total annual electrical energy consumption (kWh), and
- H_e = 3412 Btus/kWh, conversion factor.

The total annual gas and electrical energy consumptions are, in turn, represented by Eqs. 11 and 12.

$$E_{AOG} = E_{CO} + E_{PO} + E_{SC} \quad (11)$$

where:

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

$$E_{AOE} = E_{SO} + E_{SS} + E_{CL} \quad (12)$$

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., fuel) energy consumption (E_{CO} , E_{PO} , E_{SC}) are represented by Eqs. 13, 14, and 15.

$$E_{CO} = (O_O / \text{Eff}) - [(E_{IO} * H_e * O_O) / (W_1 * C_p * T)] \quad (13)$$

where:

- O_O = annual useful cooking-energy output (Btus),
- 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.

$$E_{PO} = P * (A-B) \quad (14)$$

where:

- P = pilot light consumption (Btus),
- 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.

$$E_{SC} = E_S * S_g \quad (15)$$

where:

- E_S = energy consumption measured during the self-cleaning operation (Btus),
- S_g = 7, average number of times a self-cleaning operation of a gas oven is used per year.

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. 13. The annual clock energy consumption (E_{CL}) is represented by Eq. 9. The annual secondary self-cleaning energy consumption (E_{SS}), is determined by using Eq. 16.

$$E_{SS} = E_{IS} * S_g * C \quad (16)$$

where:

- E_{IS} = electrical energy consumed during the self-cleaning operation (watt-hours),
- S_g = 7, 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. 5 and 7 for electric ovens, and Eqs. 10 and 13 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/year and 160,700 Btus/year for electric and gas ovens, respectively. But since these values were established by the DOE test procedure in the late 1970s, manufacturers contend that new values for the 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 "adjusted" values for the useful cooking energy output were derived from various gas and electric utility reports. The same type of analysis was conducted for ovens. For a more detailed description of the analysis, please refer to Appendix A. The "adjusted" annual useful cooking energy output values that were determined for electric and gas ovens were 35.5 kWh/year and 124,200 Btus/year, respectively. Table 1.8 presents the baseline energy factors and cooking efficiencies for the four oven product classes. As evidenced in Table 1.8, the energy factors calculated with the "adjusted" annual useful cooking output values are lower than those determined using the DOE values.

Table 1.8 Baseline Oven Energy Factors and Cooking Efficiencies

Product Class	Energy Factor		Efficiency DOE
	DOE	Adjusted	
Electric Standard	11.1%	10.9%	12.10%
Electric Self-Clean	10.9%	10.2%	13.9%
Gas Standard	3.8%	3.5%	5.92%
Gas Self-Clean	6.0%	5.8%	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 1.9. 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 Table 1.9, two values are presented for each of the following quantities: the annual cooking energy consumption, the total annual energy consumption, and the energy factor. One set of values is based on using the DOE value for the annual useful cooking-energy output (47.09 kWh/year) while the other set is based on using the "adjusted" value (35.5 kWh/year). 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 it. Refer to Eqs. 5 through 9 to determine how the above quantities were calculated. Notes are provided with Table 1.9 indicating how each design option impacts the cooking efficiency. Also included in Table 1.9 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 1.10. 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 Table 1.10, two values are presented for each of the following quantities: the annual cooking-energy consumption, the total annual energy consumption, and the energy factor. One set of values is based on using the DOE value for the annual useful cooking energy output (47.09 kWh/year) while the other set is based on using the "adjusted" value (35.5 kWh/year). Both the clock and self-cleaning energy consumptions are not a function of the annual useful cooking-energy output and are the same regardless of what value is chosen for it. Refer back to Eqs. 5 through 9 to determine how the above quantities were calculated. Notes are provided with Table 1.10 indicating how each design option impacts the cooking efficiency. Also included in Table 1.10 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 standard gas ovens are presented in Table 1.11. 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 Table 1.11, two values are presented for each of the following quantities: the annual cooking energy consumption, the annual secondary cooking-energy consumption, the total annual primary energy consumption, the total annual secondary energy consumption, and the energy factor. One set of values is based on using the DOE value for the annual useful cooking energy output (160,700 Btus/year), while the other set is based on using the "adjusted" value (124,200 Btus/year). 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 the it. Refer to Eqs. 10 through 16 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).

Table 1.9 Cost-Efficiency Table for Standard Electric Ovens

Std Level	Design No.	Design Options		Mfg. Cost 1990\$	Eff %	E _{CL} kWh	DOE			Adj		
							E _{CO} kWh	E _{AO} kWh	EF %	E _{CO} kWh	E _{AO} kWh	EF %
	0	Baseline	(1)	146.17	12.10%	33.8	389	423.0	11.1%	293	327.2	10.9%
	1	0 + Remove Oven Door Window	(2)	146.17	12.58%	33.8	374	408.0	11.5%	282	315.9	11.2%
	2	1 + Improved Door Seals	(3)	147.26	13.40%	33.8	351	385.2	12.2%	265	298.7	11.9%
	3	2 + Reduced Vent Rate	(4)	148.89	14.02%	33.8	336	369.6	12.7%	253	287.0	12.4%
1	4	3 + Reflective Surfaces	(5)	150.38	14.52%	33.8	324	358.1	13.2%	244	278.3	12.8%
2	5	4 + Added Insulation	(6)	154.62	15.92%	33.8	296	329.6	14.3%	223	256.8	13.8%
	6	5 + Forced Convection	(7)	162.84	18.68%	33.8	252	285.8	16.5%	190	223.8	15.9%
3,4	7	6 + Reduced Thermal Mass	(8)	165.28	19.33%	33.8	244	277.4	17.0%	184	217.5	16.3%
	8	7 + Improved Insulation	(9)	168.49	20.00%	33.8	235	269.3	17.5%	178	211.3	16.8%
	9	8 + Bi-Radiant Oven	(10)	230.99	27.86%	33.8	169	202.8	23.2%	127	161.2	22.0%
	10	9 + Oven Separator	(11)	242.74	28.68%	33.8	164	198.0	23.8%	124	157.6	22.5%
5	11	10 + Reduced Conduction Losses	(12)	246.29	28.73%	33.8	164	197.7	23.8%	124	157.3	22.6%

Notes

- 1 Baseline: Cooking Efficiency = 12.10%, Clock Power = 3.9 Watts, 2" of 1.09 lb/cu ft insulation
- 2 Remove Oven Door Window: Cooking Efficiency Increase = 4.0%
- 3 Improved Door Seals: Cooking Efficiency Increase = 6.75 %
- 4 Reduced Vent Rates: Cooking Efficiency Increase = 0.62 percentage points
- 5 Reflective Surfaces: Cooking Efficiency Increase = 0.5 percentage points
- 6 Added Insulation: Cooking Efficiency Increase = 1.4 percentage points
- 7 Forced Convection: Cooking Efficiency Increase = 23%
- 8 Reduced Thermal Mass: Cooking Efficiency Increase = 5.4%
- 9 Improved Insulation: Cooking Efficiency Increase = 5.5%
- 10 Bi-Radiant Oven: Cooking Efficiency Increase = 65.0%
- 11 Oven Separator: Cooking Efficiency Increase = 0.82 percentage points
- 12 Reduced Conduction Losses: Cooking Efficiency Increase = 0.05 percentage points

Table 1.10 Cost-Efficiency Table for Self-Cleaning Electric Ovens

Std Level	Design No.	Design Options		Mfg. Cost 1990\$	Eff %	E _{CL} kWh	E _{SC} kWh	DOE			Adj		
								E _{CO} kWh	E _{AO} kWh	EF	E _{CO} kWh	E _{AO} kWh	EF
1	0	Baseline	(1)	185.15	13.90%	33.1	58.2	339	430.1	10.9%	255	346.7	10.2%
	1	0 + Remove Oven Door Window	(2)	185.15	14.45%	33.1	58.2	326	417.1	11.3%	246	336.9	10.5%
2	2	1 + Reflective Surfaces	(3)	186.98	14.95%	33.1	58.2	315	406.2	11.6%	237	328.7	10.8%
3	3	2 + Forced Convection	(4)	196.47	18.13%	33.1	58.3	260	351.2	13.4%	196	287.3	12.4%
	4	3 + Added Insulation	(5)	200.71	19.53%	33.1	58.3	241	332.6	14.2%	182	273.2	13.0%
4	5	4 + Reduced Thermal Mass	(6)	203.59	20.24%	33.1	58.3	233	324.1	14.5%	175	266.8	13.3%
	6	5 + Bi-Radiant Oven	(7)	266.09	29.27%	33.1	58.3	161	252.3	18.7%	121	212.7	16.7%
	7	6 + Oven Separator	(8)	278.29	30.09%	33.1	58.3	156	247.9	19.0%	118	209.4	17.0%
5	8	7 + Reduced Conduction Losses	(9)	282.66	30.14%	33.1	58.3	156	247.6	19.0%	118	209.2	17.0%

Notes

- 1 Baseline: Cooking Efficiency = 13.90%, Clock Power = 3.8 watts, 2" of 1.90 lb/cu ft insulation, Self-Cleaning Energy Consumption = 5286 watt-hours
- 2 Remove Oven Door Window: Cooking Efficiency Increase = 4.0%
- 3 Reflective Surfaces: Cooking Efficiency Increase = 0.5 percentage points
- 4 Forced Convection: Cooking Efficiency Increase = 23%
- 5 Added Insulation: Cooking Efficiency Increase = 1.4 percentage points
- 6 Reduced Thermal Mass: Cooking Efficiency Increase = 5.1%
- 7 Bi-Radiant Oven: Cooking Efficiency Increase = 65.0%
- 8 Oven Separator: Cooking Efficiency Increase = 0.82 percentage points
- 9 Reduced Conduction Losses: Cooking Efficiency Increase = 0.05 percentage points

Table 1.11 Cost-Efficiency Table for Standard Gas Ovens

Std Level	Design No.	Design Options		Mfg. Cost	Eff	E _{PO}	DOE					ADJ				
							E _{CO}	E _{SO}	E _{AOG}	E _{AO}	EF	E _{CO}	E _{SO}	E _{AOG}	E _{AO}	EF
							1990\$	%	kBtu	kBtu	kWh	kBtu	kWh	kBtu	kWh	kBtu
	0	Baseline	(1)	154.80	5.92%	1480.5	2717	0.0	4197.1	0.0	3.8%	2100	0.0	3580.1	0.0	3.5%
	1	0 + Remove Oven Door Window	(2)	154.80	6.15%	1480.5	2612	0.0	4092.7	0.0	3.9%	2019	0.0	3499.4	0.0	3.5%
1	2	1 + Electric Ignition	(3)	160.72	6.06%	0.0	2441	61.8	2441.5	61.8	6.1%	1887	47.8	1886.9	47.8	6.1%
	3	2 + Reduced Vent Rate	(4)	162.35	6.68%	0.0	2195	61.8	2195.2	61.8	6.7%	1697	47.8	1696.6	47.8	6.7%
	4	3 + Improved Door Seals	(5)	163.44	7.09%	0.0	2055	61.8	2054.7	61.8	7.1%	1588	47.8	1588.1	47.8	7.1%
	5	4 + Reflective Surfaces	(6)	164.96	7.59%	0.0	1906	61.8	1905.5	61.8	7.6%	1473	47.8	1472.7	47.8	7.6%
2	6	5 + Added Insulation	(7)	169.20	8.99%	0.0	1576	61.8	1576.0	61.8	9.0%	1218	47.8	1218.1	47.8	9.0%
	7	6 + Forced Convection	(8)	178.49	10.34%	0.0	1325	67.1	1324.7	67.1	10.3%	1024	51.9	1023.8	51.9	10.3%
	8	7 + Reduced Thermal Mass	(9)	180.97	10.57%	0.0	1292	67.1	1292.1	67.1	10.6%	999	51.9	998.6	51.9	10.6%
3,4	9	8 + Improved Insulation	(10)	184.55	10.86%	0.0	1251	67.1	1251.2	67.1	10.9%	967	51.9	967.0	51.9	10.9%
	10	9 + Oven Separator	(11)	212.81	11.53%	0.0	1165	67.1	1164.8	67.1	11.5%	900	51.9	900.2	51.9	11.5%
5	11	10 + Reduced Conduction Losses	(12)	216.44	11.58%	0.0	1159	67.1	1158.7	67.1	11.6%	896	51.9	895.6	51.9	11.6%

Notes:

- 1 Baseline: Cooking Efficiency = 5.92%, 2" of 1.09 lb/cu ft insulation, Standing Pilot Ignition = 175 Btu/hour
- 2 Remove Oven Door Window: Cooking Efficiency Increase = 4.0%
- 3 Electric Ignition: Cooking Efficiency Decrease = 0.09 percentage points, Added Electricity Consumption = 176 watt-hours
- 4 Reduced Vent Rates: Cooking Efficiency Increase = 0.62 percentage points
- 5 Improved Door Seals: Cooking Efficiency Increase = 7.0 %
- 6 Reflective Surfaces: Cooking Efficiency Increase = 0.5 percentage points
- 7 Added Insulation: Cooking Efficiency Increase = 1.4 percentage points
- 8 Forced Convection: Cooking Efficiency Increase = 23%, Added Electricity Consumption = 15 watt-hours
- 9 Reduced Thermal Mass: Cooking Efficiency Increase = 3.9%
- 10 Improved Insulation: Cooking Efficiency Increase = 4.9%
- 11 Oven Separator: Cooking Efficiency Increase = 0.67 percentage points
- 12 Reduced Conduction Losses: Cooking Efficiency Increase = 0.05 percentage points

The results of the energy efficiency analysis for self-cleaning gas ovens are presented in Table 1.12. 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 Table 1.12, two values are presented for each of the following quantities: the annual cooking-energy consumption, the annual secondary cooking-energy consumption, the total annual primary energy consumption, the total annual secondary energy consumption, and the energy factor. One set of values is based on using the DOE value for the annual useful cooking energy output (160,700 Btu's/year) while the other set is based on using the "adjusted" value (124,200 Btus/year). 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 it. Refer to Eqs. 10 through 16 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 1.12 Cost-Efficiency Table for Self-Cleaning Gas Ovens

Std Level	Design No.	Design Options	Mfg. Costs	Eff	E _{SC}	E _{SS}	E _{CL}	DOE					ADJ					
								E _{CO}	E _{SO}	E _{AOG}	E _{AO} E	EF	E _{CO}	E _{SO}	E _{AOG}	E _{AO}	EF	
								1990\$	%	kBtu	kWh	kWh	kBtu	kWh	kBtu	kWh	%	kBtu
1	0	Baseline	(1)	220.26	7.13%	302.1	1.2	31.3	2044	61.8	2346.5	94.3	6.0%	1580	47.8	1882.1	80.3	5.8%
	1	0 + Remove Oven Door Window	(2)	220.26	7.41%	302.1	1.2	31.3	1958	61.8	2259.7	94.3	6.2%	1513	47.8	1815.1	80.3	5.9%
2	2	1 + Improved Door Seals	(3)	221.38	7.91%	302.1	1.2	31.3	1821	61.8	2123.0	94.3	6.6%	1407	47.8	1709.4	80.3	6.3%
3	3	2 + Reflective Surfaces	(4)	223.21	8.41%	302.1	1.2	31.3	1700	61.8	2002.1	94.3	6.9%	1314	47.8	1616.0	80.3	6.6%
	4	3 + Added Insulation	(5)	227.45	9.81%	302.1	1.2	31.3	1427	61.8	1729.4	94.3	7.8%	1103	47.8	1405.2	80.3	7.4%
4	5	4 + Reduced Thermal Mass	(6)	230.33	10.13%	302.1	1.2	31.3	1376	61.8	1677.7	94.3	8.0%	1063	47.8	1365.2	80.3	7.6%
	6	5 + Forced Convection	(7)	241.34	11.76%	302.1	1.3	31.3	1138	67.1	1440.1	99.7	9.0%	880	51.9	1181.6	84.5	8.4%
	7	6 + Reduced Conduction Losses	(8)	245.71	11.81%	302.1	1.3	31.3	1132	67.1	1434.3	99.7	9.1%	875	51.9	1177.2	84.5	8.5%
5	8	7 + Oven Separator	(9)	291.68	12.33%	302.1	1.3	31.3	1074	67.1	1376.3	99.7	9.4%	830	51.9	1132.3	84.5	8.7%

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 Btus
- 2 Remove Oven Door Window: Cooking Efficiency Increase = 4.0%
- 3 Improved Door Seals: Cooking Efficiency Increase = 7.0%
- 4 Reflective Surfaces: Cooking Efficiency Increase = 0.5 percentage points
- 5 Added Insulation: Cooking Efficiency Increase = 1.4 percentage points
- 6 Reduced Thermal Mass: Cooking Efficiency Increase = 4.9%
- 7 Forced Convection: Cooking Efficiency Increase = 23%, Added Electricity Consumption (during cooking and cleaning cycles) = 15 Watt-hours
- 8 Reduced Conduction Losses: Cooking Efficiency Increase = 0.05 percentage points
- 9 Oven Separator: Cooking Efficiency Increase = 0.53 percentage points

The four oven product classes all have similar maximum technologically feasible designs. The "max tech" design for each oven product class incorporates the following: a windowless oven door, reflective surfaces on the interior cavity walls, added insulation in the walls and door, forced convection cooking, reduced thermal mass within the oven cavity, an oven separator, and an upgraded oven door to reduce conduction losses. In addition to the above improvements, the standard electric oven's "max tech" design includes improved insulation (1.90 lb/cu ft) in the walls and door, an improved vent design that reduces the oven's vent rate, improved oven door seals, and a bi-radiant oven design. The "max tech" design for the standard gas oven also includes improved insulation, an improved vent design, and improved door seals as well as an electric ignition system. The self-cleaning electric oven's "max tech" design also includes a bi-radiant oven design while the "max tech" design for the self-cleaning gas oven includes improved door seals.

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. If the value listed in the DOE test procedure is used, the minimum energy consumptions for the four oven product classes are 197.7 kWh/year for standard electric ovens, 247.6 kWh/year for self-cleaning electric ovens, 1158.7 Btus/year and 67.1 kWh/year for standard gas ovens, and 1376.3 Btus/year and 99.7 kWh/year for self-cleaning gas ovens. If the "adjusted" annual useful cooking energy output value is used, the minimum energy uses are: 157.3 kWh/year for standard electric ovens, 209.2 kWh/year for self-cleaning electric ovens, 895.6 Btus/year and 51.9 kWh/year for standard gas ovens, and 1132.3 Btus/year and 84.5 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 U.S. Department of Energy Engineering Analysis for residential appliances (43) established a relationship between oven volume and energy factor from data compiled by the National Bureau of Standards (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 1.13 presents the intercepts for each of the trial standard levels that have been chosen for the four oven product

classes. Since there are two sets of energy factors (DOE and "adjusted") established for each product class, two sets of intercepts are presented for each standard level.

Table 1.13 Intercepts for Energy Factor vs. Volume Relationships

Std Level	PRODUCT CLASSES							
	Standard Electric		Self-Clean Electric		Standard Gas		Self-Clean Gas	
	DOE	Adjusted	DOE	Adjusted	DOE	Adjusted	DOE	Adjusted
1	0.193	0.189	0.171	0.164	0.089	0.089	0.089	0.086
2	0.204	0.199	0.177	0.169	0.118	0.118	0.094	0.091
3	0.231	0.224	0.195	0.185	0.137	0.137	0.098	0.094
4	0.231	0.224	0.207	0.194	0.137	0.137	0.109	0.104
5	0.299	0.287	0.251	0.231	0.144	0.144	0.122	0.116

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 the net present value to the consumer of maintaining the operation of the oven. All design options, for both electric and gas ovens, were assumed to yield no increase to the cost of maintaining the operation of the oven.

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. For both electric and gas ovens, design options were assumed to yield no increase to the installation cost of the oven.

The cost and efficiency data were combined and presented in Tables 1.9 to 1.12, in the previous section on Energy Use Data for Ovens. Appendix A.2 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 U.S. Department of Energy Engineering Analysis for residential appliances (44) 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 Lawrence Berkeley Laboratory (45) 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 (46) was used to estimate the cost of producing a bi-radiant electric oven. An energy-efficient electrical product knowledge base prepared by ORTECH International (47) for the Canadian Electrical Association was used to estimate the cost of improving door seals in gas ovens and standard electric ovens. And finally, it was assumed that no additional manufacturing cost were associated with removing an oven door window.

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 1.9 through 1.12 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. In addition, since each product class has two sets of energy factors calculated for each design option (one set based on the DOE test procedure value for the annual useful cooking energy output and the other set based on an "adjusted" value), two different 95% confidence intervals have been established for each of the "max tech" design's energy factors.

The low and high ends of the 95% confidence interval for standard electric ovens are approximately the same for both the types of "max tech" energy factors. 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 than 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 for both DOE and "adjusted" "max tech" energy factors. 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 range of the 95% confidence interval for standard gas ovens is exactly the same for both the "DOE" and "adjusted" "max tech" energy factors. 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 range of the 95% confidence interval for self-cleaning gas ovens varies only slightly between the two types of energy factors calculated for the "max tech" design. In both energy factor cases (DOE and "adjusted"), 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 A of the Technical Support Document 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 1.14. A microwave oven operates by generating microwave energy at a frequency that is absorbed by the water molecules in food.

Table 1.14 Design Options for Microwave Ovens

Use Reflective Surfaces
Use More Efficient Fan
Improve Efficiency of the Magnetron
Improve Efficiency of the Power Supply
Modify Wave Guide
Eliminate or Improve Ceramic Stirrer Cover

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 (48).

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 1% (49).

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.

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% (50). The mean magnetron efficiency is approximately 71%. Domestic companies do not produce magnetrons of the size that is used in microwave ovens.

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 possible. (51)

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 (52). These stirrers absorb some microwave energy but are needed to prevent food splatter inside the wave guide.

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 (53).

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 mostly obtained from manufacturers' literature. For cavity sizes from

0.3 to 1.4 ft³, input electric power varies from 800 to 1650 watts. The efficiency, which is the useful power output divided by the electric power input, ranges from 47 to 61%. AHAM supplied some data (reported by AHAM members) on microwave oven efficiency. These data indicated that the efficiency ranged from 47.7 to 59.8%, with a shipment weighted-average efficiency of 54.4%. Shipments of one product purchased from one major supplier were removed by AHAM because the efficiency data were not verified.

Baseline data for four models were also provided by AHAM. The average input power for these four models is equal to 1423 watts. This input electric power was chosen for the baseline model. Power for the magnetron tube filament and fan/other are assumed to be 37 and 50 watts, respectively.

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 deliverance of microwave energy to the food in the oven cavity (there are 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 (54):

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

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 0.85, 0.71, and 0.95, respectively. The resulting efficiency calculated with the equation above is 0.54.

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. If the high-voltage power supply efficiency is increased from 85 to 96%, the microwave oven efficiency is increased to 61%. Table 1.15 summarizes the efficiency, energy use, and manufacturer cost for each design option considered.

Annual energy use is computed in two different ways. One method uses the DOE test procedure energy use value of 75.0 kWh/yr. That value is based on 1976 data. The second method uses more recent field use data gathered by electric utility companies (55). The proposed changes to the test procedure for microwave ovens includes a change to a higher usage of 270 kWh/yr.

For the baseline microwave oven, auxiliary power was assumed to be equal to 87 watts, or 6.1% of total input power. If the efficiency of the fan motor is increased so as to reduce the power demand for fan/other from 50 to 26 watts, this results in P_{aux}/P_{in} decreasing to 0.45. Using this new value for P_{aux}/P_{in} , results in an efficiency of 61.8% for the microwave oven.

Other small improvements in microwave oven efficiency are possible through improvements in the cavity and magnetron efficiencies. If the cavity efficiency is increased to 96% by modification of the wave guide, the microwave oven efficiency increases to 62.5%. An improvement in magnetron efficiency from 71 to 72% increases overall microwave oven efficiency to 63.4%. An additional increase in cavity efficiency to 97%, through the improvement of the reflective surfaces, yields a microwave oven efficiency of 63.9%. This is the maximum technologically feasible efficiency for microwave ovens as measured through the 1988 IEC test procedure.

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 \$5 incremental manufacturer cost was obtained from the average of estimates from two transformer companies (56) (57). The disaggregated manufacturer's costs can be found in Appendix A.2.

Table 1.15 Cost-Efficiency Data for a Microwave Oven

Design Option	Mfg Cost (1990\$)	Efficiency (%)	Energy Use* (kWh/yr)	Energy Use† (kWh/yr)
Baseline	120.00	54.0	270.0	75.0
0+Eff Power Supply	125.00	61.0	239.0	66.4
1+Eff Fan	126.05	61.8	236.0	65.6
2+ Modified Wave Guide	127.90	62.5	233.3	64.8
3+Impr Magn	140.40	63.4	230.0	64.2
4+ Refl Surf	156.80	63.9	228.2	63.4

*For new energy use data, energy use for each design is computed by dividing 270×0.54 , or 145.8 kWh/yr, by the efficiency.

†For the existing DOE test procedure energy use calculation, energy use is computed by dividing 75 kWh/yr $\times 0.54$, or 40.5 kWh/yr, by the efficiency.

1.5.4 Maximum Technologically Feasible Design

The maximum technologically feasible efficiency is achieved by combining the five design options described above. The resultant microwave oven efficiency is 63.9%; this is greater than the highest efficiency model presently available. The incremental manufacturer cost to achieve this efficiency is \$36.80. 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 62.7 and 65.1%. For incremental manufacturer costs, 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 \$4.00 and \$6.00.

CHAPTER 2. BASE CASE FORECASTS: KITCHEN RANGES AND OVENS

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

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, multifamily, 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 A, Chapter 5 of this Technical Support Document.

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 Ranges and Ovens

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

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 LBL-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	Average Energy Factor				
	Electric Cooktop	Gas Cooktop	Electric Oven	Gas Oven	Microwave Oven
1981	0.763	0.188	0.105	0.041	0.540
1990	0.763	0.188	0.108	0.061	0.540
1996	0.763	0.188	0.108	0.061	0.540
2000	0.763	0.194	0.108	0.061	0.540
2030	0.791	0.194	0.113	0.070	0.610

Source: LBL-REM (1980-2030).

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

Year	Unit Energy Consumption				
	Electric Cooktop (kWh)	Gas Cooktop (MMBtu)	Electric Oven (kWh)	Gas Oven (MMBtu)	Microwave Oven (kWh)
1981	274.5	3.89	338.1	3.24	270.0
1990	274.5	3.89	327.7	2.06	270.0
1996	274.5	3.89	327.7	2.06	270.0
2000	274.5	3.76	327.7	2.06	270.0
2030	265.2	3.76	315.5	1.80	239.0

Source: LBL-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.

Table 2.3 Projected Average Usage of Cooktops and Ovens

Year	Usage Factor				
	Electric Cooktop	Gas Cooktop	Electric Oven	Gas Oven	Microwave Oven
1981	0.895	0.959	0.905	0.949	0.967
1990	0.845	0.954	0.857	0.944	0.939
1996	0.892	0.982	0.899	0.991	0.938
2000	0.931	0.999	0.934	1.025	0.941
2030	0.940	0.947	0.943	0.993	0.948

Source: LBL-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 LBL-REM. LBL-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 association data) and surveys of appliance ownership (e.g., from DOE/EIA RECS 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 (Thousands)

Year	Electric Cooktop	Gas Cooktop	Electric Oven	Gas Oven	Microwave Oven
1981	2790	1696	2637	1804	7586
1990	3442	2346	3174	2546	7791
1996	3755	2390	3469	2600	8742
2000	3777	2467	3492	2691	9819
2030	4870	2823	4327	3292	12719

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
1980	53	46	56	42	17
1990	59	41	57	41	70
1996	60	39	57	41	80
2000	61	38	56	42	84
2030	62	38	56	43	95

Source: LBL-REM.

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 (engineering estimate); and usage behavior factor.

Table 2.6 shows the 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)

Year	Electric Cooktop	Gas Cooktop	Electric Oven	Gas Oven	Microwave Oven	Total
1981	0.52	0.32	0.55	0.29	0.16	1.74
1990	0.34	0.24	0.38	0.20	0.19	1.35
1996	0.23	0.18	0.25	0.13	0.24	1.02
2000	0.19	0.16	0.22	0.10	0.26	0.93
2030	0.23	0.17	0.25	0.10	0.32	1.07

Source: LBL-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	196	220	508	523	186
1990	196	220	508	533	186
1996	196	220	508	533	186
2000	196	222	508	533	186
2030	201	222	511	540	192

Source: LBL-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 1992 to 2030, electricity prices are 3% lower while gas and distillate prices are 5% lower than those in the AEO 1991 forecast.
4. *Higher Energy Price.* Assume higher energy prices. Starting from 1992 to 2030, electricity prices are 3% higher while gas and distillate prices are 5% higher than those in the AEO 1991 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	1990	1996	2000	2030
Reference	196	196	196	196	201
1	148	151	151	151	151
2	245	245	245	245	245
3	196	196	196	196	201
4	196	196	196	196	201
5	196	252	294	294	294
6	196	196	201	201	201

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

Year:	1981	1990	1996	2000	2030
Reference	220	220	220	222	222
1	198	199	199	199	199
2	242	242	242	242	244
3	220	220	220	220	222
4	220	220	222	222	222
5	220	221	232	240	331
6	220	220	222	222	333

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

Year:	1981	1990	1996	2000	2030
Reference	508	508	508	508	511
1	456	470	470	470	473
2	559	559	559	559	559
3	508	508	508	508	511
4	508	508	508	508	511
5	508	509	526	542	762
6	508	508	511	511	538

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

Year:	1981	1990	1996	2000	2030
Reference	523	533	533	533	540
1	419	428	428	428	443
2	626	631	639	639	641
3	523	533	533	533	540
4	523	533	533	533	541
5	523	528	535	540	687
6	523	533	533	533	563

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

Year:	1981	1990	1996	2000	2030
Reference	186	186	186	186	192
1	149	153	153	153	153
2	223	223	223	223	223
3	186	186	186	186	192
4	186	186	186	186	192
5	186	188	209	233	233
6	186	186	192	192	192

Source: LBL-REM.

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

Year:	1981	1990	1996	2000	2030
Reference	274.5	274.5	274.5	274.5	265.2
1	274.5	265.2	265.2	265.2	265.2
2	274.5	274.5	274.5	274.5	274.5
3	274.5	274.5	274.5	274.5	265.2
4	274.5	274.5	274.5	274.5	265.2
5	274.5	269.2	257.8	257.8	257.8
6	274.5	274.5	265.2	265.2	265.2

Table 2.9b Average Unit Consumption of New Gas Cooktops (Weighted-Average in MMBtu/year)

Year:	1981	1990	1996	2000	2030
Reference	3.89	3.89	3.89	3.76	3.76
1	3.90	3.80	3.80	3.80	3.80
2	3.90	3.90	3.90	3.90	3.80
3	3.90	3.90	3.90	3.90	3.80
4	3.90	3.90	3.80	3.80	3.80
5	3.90	3.80	3.60	3.40	1.70
6	3.90	3.90	3.80	3.80	1.70

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

Year:	1981	1990	1996	2000	2030
Reference	338.1	327.7	327.7	327.7	315.5
1	338.1	279.3	279.3	279.3	271.9
2	338.1	327.7	327.7	327.7	327.7
3	338.1	327.7	327.7	327.7	315.5
4	338.1	327.7	327.7	327.7	315.5
5	338.1	325.0	289.1	266.6	186.4
6	338.1	327.7	315.5	315.5	275.4

Table 2.9d Average Unit Consumption of New Gas Ovens (Weighted-Average in MMBtu/year)

Year:	1981	1990	1996	2000	2030
Reference	3.24	2.06	2.06	2.06	1.80
1	3.20	1.90	1.90	1.90	1.30
2	3.20	2.40	2.10	2.10	2.00
3	3.20	2.10	2.10	2.10	1.80
4	3.20	2.10	2.10	2.10	1.80
5	3.20	2.30	2.10	1.90	1.00
6	3.20	2.10	2.10	2.10	1.30

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

Year:	1981	1990	1996	2000	2030
Reference	270.0	270.0	270.0	270.0	239.0
1	270.0	239.0	239.0	239.0	239.0
2	270.0	270.0	270.0	270.0	270.0
3	270.0	270.0	270.0	270.0	239.0
4	270.0	270.0	270.0	270.0	239.0
5	270.0	260.3	230.4	228.2	228.2
6	270.0	270.0	239.0	239.0	239.0

Source: LBL-REM.

CHAPTER 3. PROJECTED NATIONAL IMPACTS OF STANDARDS: KITCHEN RANGES AND OVENS

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

The principal outputs from the LBL-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 trial standards case.

These outputs are provided annually (or for selected years) and cumulatively over a period of time, i.e., 1996-2030. Energy savings are given for each year from implementation of standards to the end of the period. Net present value of the standards 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 trial standards 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. Section 3.5 presents net present value and Section 3.6 discusses the results of the sensitivity analyses.

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

3.1 STANDARDS LEVELS

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

Table 3.1 Trial Standards Levels for Cooktops, Ovens and Microwave Ovens

	Trial Standard Level				
	1	2	3	4	5
Engineering design option:					
Electric Cooktop, Coil Element	0	1	2	2	2
Electric Cooktop, Smooth Element	0	0	0	1	2
Gas Cooktop	1	2	4	4	4
Electric Oven, Non-Self-cleaning	4	5	7	7	11
Electric Oven, Self-Cleaning	0	2	3	5	8
Gas Oven, Non-Self-Cleaning	2	6	9	9	11
Gas Oven, Self-Cleaning	0	2	3	5	8
Microwave Oven	1	2	3	4	5
Maximum annual energy consumption :					
Electric Cooktop, Coil Element (kWh)	271	260	258	258	258
Electric Cooktop, Smooth Element (kWh)	294	294	294	259	289
Gas Cooktop (MMBtu)	3.76	1.71	1.63	1.63	1.63
Electric Oven, Non-Self-cleaning (kWh)	278	257	218	218	157
Electric Oven, Self-Cleaning (kWh)	347	329	287	267	209
Gas Oven, Non-Self-Cleaning (MMBtu)	1.89	1.22	0.97	0.97	0.90
Gas Oven, Self-Cleaning (MMBtu)	1.88	1.71	1.62	1.37	1.13
Microwave Oven (kWh)	239	236	233	230	228

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 1990 to 1996 in the absence of amended standards.

Table 3.2a Unit Energy Consumption for New Electric Cooktops (Weighted-Average kWh/year)

Year	Base	Trial Standard Level				
		1	2	3	4	5
1981	275					
1990	275					
1996	275	275	265	263	262	258
2000	275	275	265	263	262	258
2015	265	265	265	263	262	258
2030	265	265	265	263	262	258

Table 3.2b Unit Energy Consumption for New Gas Cooktops (Weighted-Average Million Btu/Year)

Year	Base	Trial Standard Level				
		1	2	3	4	5
1981	3.9					
1990	3.9					
1996	3.9	3.8	1.7	1.6	1.6	1.6
2000	3.8	3.8	1.7	1.6	1.6	1.6
2015	3.8	3.8	1.7	1.6	1.6	1.6
2030	3.8	3.8	1.7	1.6	1.6	1.6

Table 3.2c Unit Energy Consumption for New Electric Oven (Weighted-Average kWh/year)

Year	Base	Trial Standard Level				
		1	2	3	4	5
1981	338					
1990	328					
1996	328	311	297	257	245	186
2000	328	311	297	257	245	186
2015	316	307	297	257	245	186
2030	316	307	297	257	245	186

Table 3.2d Unit Energy Consumption for New Gas Oven (Weighted-Average Million Btu/Year)

Year	Base	Trial Standard Level				
		1	2	3	4	5
1981	3.2					
1990	2.1					
1996	2.1	1.7	1.3	1.1	1.1	1.0
2000	2.1	1.7	1.3	1.1	1.1	1.0
2015	2.1	1.7	1.3	1.1	1.1	1.0
2030	1.8	1.6	1.3	1.1	1.1	1.0

Table 3.2e Unit Energy Consumption for New Microwave Oven (kWh/Year)

Year	Base	Trial Standard Level				
		1	2	3	4	5
1981	270					
1990	270					
1996	270	239	236	233	230	228
2000	270	239	236	233	230	228
2015	239	239	236	233	230	228
2030	239	239	236	233	230	228

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. Standards are projected to produce cumulative energy savings for cooktops from 0.02 Quads for standards level 1 to 3.04 Quads for standards level 5, during the period 1996-2030. For the same time period, cumulative energy savings for ovens range from 0.69 Quads for standard level 1 to 3.88 Quads for standard level 5. For microwave ovens, the cumulative energy savings during the period 1996-2030 range from 0.46 Quads for standard level 1 to 0.84 Quads for standard level 5.

Table 3.3a U.S. Energy Consumption for Electric Cooktops (Quadrillion Btu, Primary)

Year	Base	Trial Standard Level				
		1	2	3	4	5
1981	0.517					
1990	0.345					
1996	0.227	0.227	0.226	0.227	0.224	0.222
2000	0.194	0.194	0.192	0.193	0.188	0.183
2015	0.214	0.214	0.208	0.210	0.195	0.182
2030	0.230	0.230	0.223	0.225	0.209	0.195
1996-2030	7.45	7.45	7.28	7.35	6.92	6.56
Cumulative Savings:		0.01	0.17	0.10	0.53	0.89
Percent of Base:		0.1%	1.2%	0.7%	3.9%	6.7%

Table 3.3b U.S. Energy Consumption for Gas Cooktops (Quadrillion Btu, Primary)

Year	Base	Trial Standard Level				
		1	2	3	4	5
1981	0.320					
1990	0.239					
1996	0.177	0.177	0.164	0.161	0.163	0.164
2000	0.160	0.160	0.129	0.124	0.128	0.130
2015	0.170	0.170	0.085	0.079	0.088	0.094
2030	0.173	0.173	0.090	0.084	0.093	0.099
1996-2030	5.94	5.93	3.57	3.36	3.62	3.79
Cumulative Savings:		0.01	2.37	2.58	2.32	2.15
Percent of Base:		0.1%	17.7%	19.3%	17.4%	16.0%

Table 3.3c U.S. Energy Consumption for Electric + Gas Cooktops (Quadrillion Btu, Primary)

Year	Base	Trial Standard Level				
		1	2	3	4	5
1981	0.837					
1990	0.584					
1996	0.404	0.403	0.390	0.388	0.387	0.386
2000	0.354	0.354	0.321	0.317	0.316	0.313
2015	0.384	0.384	0.293	0.289	0.283	0.276
2030	0.403	0.403	0.313	0.309	0.302	0.294
1996-2030	13.39	13.37	10.85	10.71	10.54	10.35
Cumulative Savings:		0.02	2.54	2.68	2.85	3.04
Percent of Base:		0.1%	18.9%	20.0%	21.3%	22.7%

Table 3.3d U.S. Energy Consumption for Electric Ovens (Quadrillion Btu, Primary)

Year	Base	Trial Standard Level				
		1	2	3	4	5
1981	0.548					
1990	0.375					
1996	0.252	0.251	0.250	0.247	0.246	0.241
2000	0.218	0.214	0.211	0.203	0.201	0.188
2015	0.235	0.225	0.216	0.194	0.186	0.153
2030	0.249	0.240	0.232	0.208	0.200	0.164
1996-2030	8.20	7.92	7.69	7.06	6.85	5.91
Cumulative Savings:		0.28	0.51	1.14	1.35	2.29
Percent of Base:		3.4%	6.2%	13.9%	16.4%	28.0%

Table 3.3e U.S. Energy Consumption for Gas Ovens (Quadrillion Btu, Primary)

Year	Base	Trial Standard Level				
		1	2	3	4	5
1981	0.289					
1990	0.204					
1996	0.130	0.128	0.125	0.123	0.122	0.121
2000	0.105	0.100	0.093	0.088	0.087	0.083
2015	0.108	0.092	0.073	0.061	0.058	0.050
2030	0.105	0.092	0.078	0.065	0.062	0.053
1996-2030	3.76	3.35	2.85	2.51	2.42	2.18
Savings:		0.41	0.91	1.25	1.34	1.59
Percent of Base:		10.8%	24.1%	33.4%	35.6%	42.2%

Table 3.3f U.S. Energy Consumption for Electric + Gas Ovens (Quadrillion Btu, Primary)

Year	Base	Trial Standard Level				
		1	2	3	4	5
1981	0.837					
1990	0.579					
1996	0.382	0.379	0.375	0.370	0.368	0.362
2000	0.323	0.314	0.304	0.291	0.288	0.272
2015	0.343	0.317	0.289	0.255	0.244	0.203
2030	0.354	0.332	0.310	0.273	0.262	0.217
1996-2030	11.96	11.27	10.54	9.56	9.27	8.08
Savings:		0.69	1.41	2.40	2.69	3.88
Percent of Base:		5.7%	11.8%	20.0%	22.5%	32.4%

Table 3.3g U.S. Energy Consumption for Microwave Ovens (Quadrillion Btu, Primary)

Year	Base	Trial Standard Level				
		1	2	3	4	5
1981	0.063					
1990	0.193					
1996	0.239	0.230	0.229	0.228	0.227	0.226
2000	0.264	0.244	0.242	0.240	0.238	0.236
2015	0.298	0.286	0.283	0.280	0.276	0.274
2030	0.321	0.321	0.318	0.315	0.311	0.308
1996-2030	10.23	9.77	9.67	9.57	9.46	9.40
Savings:		0.46	0.57	0.67	0.77	0.84
Percent of Base:		4.5%	5.5%	6.4%	7.6%	8.2%

3.3 ANNUAL INSTALLATIONS

As shown in Table 3.4a through 3.4c, installations¹ of cooking equipment are affected by standards. 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 11.8% decrease and no increase from base for the various standards levels for cumulative shipments of electric cooktops from 1996 to 2030. For gas cooktops the projections show a change of between no decrease and 18.9% increase. For electric ovens, the projections show a change of 1.0% decrease and 5.6% increase. For gas ovens, the projections show a change of 7.4% decrease and 1.3% increase. For microwave ovens, the projections show a change of 0.05% decrease and 0.01% 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)

1996-2030	Trial Standard Level					
	Base	1	2	3	4	5
Electric	146.45	146.44	143.76	146.50	136.26	129.21
Gas	90.96	90.97	93.66	90.92	101.14	108.18
Total	237.41	237.41	237.42	237.42	237.40	237.39
Change from Base:						
Electric		-0.01	-2.69	0.05	-10.19	-17.24
Gas		0.01	2.70	-0.04	10.18	17.22
Total		0.00	0.01	0.01	-0.01	-0.02
Percent Change:						
Electric		0.0%	-1.8%	0.0%	-7.0%	-11.8%
Gas		0.0%	3.0%	0.0%	11.2%	18.9%
Total		0.0%	0.0%	0.0%	0.0%	0.0%

Table 3.4b Cumulative Installations of Ovens (Millions)

1996-2030	Trial Standard Level					
	Base	1	2	3	4	5
Electric	133.4	132.3	132.1	134.6	134.8	140.9
Gas	101.8	102.9	103.1	100.7	100.5	94.3
Total	235.2	235.2	235.2	235.2	235.2	235.2
Change from Base:						
Electric		-1.1	-1.3	1.2	1.4	7.5
Gas		1.1	1.3	-1.1	-1.4	-7.5
Total		0.0	0.0	0.0	0.0	0.0
Percent Change:						
Electric		-0.8%	-1.0%	0.9%	1.0%	5.6%
Gas		1.1%	1.3%	-1.1%	-1.3%	-7.4%
Total		0.0%	0.0%	0.0%	0.0%	0.0%

Table 3.4c Cumulative Installations of Microwave Ovens (Millions)

1996-2030	Trial Standard Level					
	Base	1	2	3	4	5
Electric	390.1	390.1	390.1	390.1	390.0	389.9
Change from Base:						
		0.0	0.0	0.0	-0.1	-0.2
Percent Change:						
		0.01%	0.01%	0.01%	-0.02%	-0.05%

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 standards come into effect.

Table 3.5a Average Purchase Price for New Electric Cooktop (1990 Dollars Per Unit)

Year	Base	Trial Standard Level				
		1	2	3	4	5
1981	196.5					
1990	196.5					
1996	196.5	196.5	200.6	206.1	258.1	293.7
2000	196.5	196.5	200.6	206.1	258.1	293.7
2015	200.6	200.6	200.6	206.1	258.1	293.7
2030	200.6	200.6	200.6	206.1	258.1	293.7

Table 3.5b Average Purchase Price for New Gas Cooktop (1990 Dollars Per Unit)

Year	Base	Trial Standard Level				
		1	2	3	4	5
1981	219.9					
1990	219.9					
1996	219.9	221.5	333.3	388.0	388.0	388.0
2000	221.5	221.5	333.3	388.0	388.0	388.0
2015	221.5	221.5	333.3	388.0	388.0	388.0
2030	221.5	221.5	333.3	388.0	388.0	388.0

Table 3.5c Average Purchase Price for New Electric Oven (1990 Dollars Per Unit)

Year	Base	Trial Standard Level				
		1	2	3	4	5
1981	508					
1990	508					
1996	508	511	519	544	557	762
2000	508	511	519	544	557	762
2015	511	514	519	544	557	762
2030	511	514	519	544	557	762

Table 3.5d Average Purchase Price for New Gas Oven (1990 Dollars Per Unit)

Year	Base	Trial Standard Level				
		1	2	3	4	5
1981	523					
1990	533					
1996	533	536	550	576	582	706
2000	533	536	550	576	582	706
2015	533	536	550	576	582	706
2030	540	541	550	576	582	706

Table 3.5e Average Purchase Price for New Microwave Oven (1990 Dollars Per Unit)

Year	Base	Trial Standard Level				
		1	2	3	4	5
1981	186					
1990	186					
1996	186	192	193	195	211	233
2000	186	192	193	195	211	233
2015	192	192	193	195	211	233
2030	192	192	193	195	211	233

3.5 NET PRESENT VALUE

The net present value (NPV) of standards for any product is calculated by first determining the difference in present value of unit life-cycle costs between the base case and standards case each year. That difference is then multiplied by the standards case shipments for the year. The net present value for the period (1996-2030) is the sum over the years of the annual values. A positive NPV of standards results when the new units in the standards 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 trial standards levels.

Table 3.6a Net Present Value for Cooktops Purchased from 1996-2030 (Billion 1990\$ Discounted at 7%)²

	Trial Standard Level				
	1	2	3	4	5
Fuel costs savings:					
Electric	0.00	0.19	0.26	0.27	0.38
Gas	0.02	5.66	5.72	6.36	6.80
TOTAL benefit (energy):	0.02	5.86	5.98	6.62	7.18
Equipment costs:					
Electric	0.00	0.19	0.59	3.99	6.02
Gas	0.00	2.65	3.82	4.25	4.55
TOTAL cost (equipment):	0.00	2.84	4.41	8.24	10.57
NPV = benefit - cost:					
Electric	0.00	0.00	-0.32	-3.72	-5.64
Gas	0.01	3.02	1.89	2.10	2.25
TOTAL across fuels:	0.01	3.01	1.57	-1.62	-3.39
Ratio: benefit/cost:	6.3	2.1	1.4	0.8	0.7

Table 3.6b Net Present Value for Ovens Purchased from 1996-2030 (Billion 1990\$ Discounted at 7%)³

	Trial Standard Level				
	1	2	3	4	5
Fuel costs saving:					
Electric	0.39	0.77	1.99	2.34	4.33
Gas	1.01	2.12	2.74	2.92	3.07
TOTAL benefit (energy):	1.40	2.89	4.73	5.27	7.40
Equipment costs:					
Electric	0.09	0.25	0.91	1.22	6.72
Gas	0.11	0.63	1.61	1.84	6.17
TOTAL cost (equipment):	0.20	0.88	2.52	3.06	12.88
NPV = benefit - cost:					
Electric	0.31	0.52	1.09	1.12	-2.38
Gas	0.90	1.49	1.13	1.08	-3.10
TOTAL across fuels:	1.20	2.01	2.22	2.20	-5.48
Ratio: Benefit/cost:	7.1	3.3	1.9	1.7	0.6

²Normalized to standards case shipments.

³Normalized to standards case shipments.

Table 3.6c Net Present Value for Microwave Ovens Purchased from 1996-2030 (Billion 1990\$ Discounted at 7% Real)⁴

	Trial Standard Level				
	1	2	3	4	5
Benefit (energy)	1.07	1.24	1.39	1.58	1.68
Cost (equipment)	0.34	0.46	0.69	2.26	4.32
NPV = benefit - cost	0.74	0.78	0.70	-0.67	-2.64
Ratio: Benefit/cost:	3.2	2.7	2.0	0.7	0.4

Source: LBL-REM.

3.6 SENSITIVITY ANALYSIS

The base case and standards levels as described above constitute a reference case against which the impacts of standards under different assumptions may be compared. The sensitivity analysis is performed by running the LBL-REM for the base case and a combined standards case that includes trial standards level 2 for cooktops, trial standard level 4 for ovens and trial standard level 3 for microwave ovens. For each sensitivity case, the results for the trial standards level are compared to the corresponding base-case run and the differences are tabulated.

The assumptions in the sensitivity cases are described in Section 2.4 and listed in Table 3.7. Tables 3.8a through 3.8e show results for cumulative energy consumption. The sensitivity analysis of product shipments is given in Tables 3.9a through 3.9e. Tables 3.10a through 3.10e show the net present values. The first line of these tables gives the results of the reference case (base case, standards level, and difference). The rest of the lines each give the results corresponding to one of the sensitivity cases, including the base case, standards case, and difference. Note that the changes in the impact of standards as a function of the changed assumptions (difference between the base and standards cases) are the principal results of the sensitivity analysis.

Table 3.7 Sensitivity Analysis Cases

Case	Description
1	Lower Equipment Prices
2	Higher Equipment Prices
3	Lower Energy Price
4	Higher Energy Price
5	High Equipment Efficiency
6	Market Discount Rates Decline

⁴Normalized to standards case shipments.

Table 3.8a Cumulative Energy Consumption of Electric Cooktops During the Period 1996-2030 (Quadrillion Btu, Primary)

	Base	Trial Standard	
		Level 2	Difference
Reference	7.45	7.28	0.17
1	7.32	7.30	0.02
2	7.53	7.25	0.28
3	7.49	7.30	0.19
4	7.41	7.26	0.15
5	6.34	6.46	-0.12
6	7.32	7.27	0.05

Table 3.8b Cumulative Energy Consumption of Gas Cooktops During the Period 1996-2030 (Quadrillion Btu, Primary)

	Base	Trial Standard	
		Level 2	Difference
Reference	5.94	3.57	2.37
1	5.92	3.50	2.42
2	5.97	3.59	2.38
3	6.01	3.59	2.42
4	5.88	3.53	2.35
5	5.91	3.84	2.07
6	5.89	3.53	2.36

Table 3.8c Cumulative Energy Consumption of Electric Ovens During the Period 1996-2030 (Quadrillion Btu, Primary)

	Base	Trial Standard	
		Level 4	Difference
Reference	8.20	6.85	1.35
1	7.27	6.70	0.57
2	8.30	6.87	1.43
3	8.26	6.87	1.39
4	8.14	6.82	1.32
5	6.55	6.22	0.33
6	7.70	6.83	0.87

**Table 3.8d Cumulative Energy Consumption of Gas Ovens During the Period 1996-2030
(Quadrillion Btu, Primary)**

	Base	Trial Standard	
		Level 4	Difference
Reference	3.76	2.42	1.34
1	3.18	2.41	0.77
2	3.83	2.43	1.40
3	3.80	2.43	1.37
4	3.72	2.41	1.31
5	3.20	2.19	1.01
6	3.44	2.42	1.02

**Table 3.8e Cumulative Energy Consumption of Microwave Ovens During the Period
1996-2030 (Quadrillion Btu, Primary)**

	Base	Trial Standard	
		Level 3	Difference
Reference	10.23	9.57	0.66
1	9.71	9.52	0.19
2	10.81	9.57	1.24
3	10.47	9.61	0.86
4	10.05	9.54	0.51
5	9.38	9.36	0.02
6	9.74	9.54	0.20

**Table 3.9a Cumulative Shipments of Electric Cooktops During the Period 1996-2030
(Millions)**

	Base	Trial Standard	
		Level 2	Difference
Reference	146	144	3
1	146	145	2
2	147	143	4
3	146	144	2
4	147	144	3
5	126	129	-3
6	146	144	2

Table 3.9b Cumulative Shipments of Gas Cooktops During the Period 1996-2030 (Millions)

	Trial Standard		
	Base	Level 2	Difference
Reference	91	94	-3
1	91	93	-2
2	91	94	-4
3	91	94	-2
4	90	94	-3
5	111	108	3
6	92	94	-2

Table 3.9c Cumulative Shipments of Electric Ovens During the Period 1996-2030 (Millions)

	Trial Standard		
	Base	Level 4	Difference
Reference	133	135	-1
1	133	134	-1
2	134	135	-2
3	133	135	-2
4	134	135	-1
5	135	142	-7
6	133	135	-2

Table 3.9d Cumulative Shipments of Gas Ovens During the Period 1996-2030 (Millions)

	Trial Standard		
	Base	Level 2	Difference
Reference	102	100	1
1	102	102	1
2	102	100	2
3	102	100	2
4	102	100	1
5	100	93	7
6	102	100	2

Table 3.9e Cumulative Shipments of Microwave Ovens During the Period 1996-2030 (Millions)

	Trial Standard		
	Base	Level 3	Difference
Reference	390	390	0
1	390	390	0
2	390	390	0
3	390	390	0
4	390	390	0
5	390	390	0
6	390	390	0

Table 3.10a Total Net Present Value to Consumers for Cooktops Sold During the Period 1996-2030 (Discounted to 1990 at 7% Real)

Case	Net Present Value (Billion 1990\$)
	Trial Standard Level 2
Reference	3.01
1	2.72
2	3.32
3	2.81
4	3.25
5	0.98
6	2.80

Table 3.10b Total Net Present Value to Consumers for Ovens Sold during the Period 1996-2030 (Discounted to 1990 at 7% Real)

Case	Net Present Value (Billion 1990\$)
	Trial Standard Level 4
Reference	2.20
1	1.61
2	1.49
3	2.07
4	2.32
5	-3.00
6	1.38

Table 3.10c Total Net Present Value to Consumers for Microwave Ovens Sold During the Period 1996-2030 (Discounted to 1990 at 7% Real)

Case	Net Present Value (Billion 1990\$)
	Trial Standard Level 3
Reference	0.70
1	-0.03
2	1.19
3	0.86
4	0.53
5	-0.13
6	-0.03

Source LBL-REM.

CHAPTER 4. LIFE-CYCLE COSTS AND PAYBACK PERIODS

The effect of standards on individual consumers includes a change in operating expense (usually decreased) and a change in purchase price (usually increased). 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 the energy price projected for 1996. Section 4.1 presents the life-cycle costs (LCC) for each design option. The results are displayed as graphs and as tables of values. Sections 4.2 through 4.4 show the impacts of standards on consumers. Section 4.5 presents the effect of different assumptions on the life-cycle cost calculations.

The *difference* due to standards is calculated (Sections 4.2 to 4.4) 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 standards. Then only those appliance purchasers who are impacted by standards (i.e., those who would have chosen a design eliminated by standards) are included in calculating the impact of standards on consumers. The impact of standards is expressed by three measures:

- Section 4.2: Payback Period (PBP),
- Section 4.3: Change in Life-Cycle Cost (LCC), and
- Section 4.4: Cost of Conserved Energy (CCE).

4.1 LIFE-CYCLE COST FOR DESIGN OPTIONS

The LCC is the sum of the purchase price (PC) and the operating expense (OC) discounted over the lifetime (N) of the appliance.

$$LCC = PC + \sum_{t=1}^N \frac{OC_t}{(1+r)^t} \quad (1)$$

If operating expenses are constant over time, Eq.1 simplifies to

$$LCC = PC + PWF \cdot OC, \quad (2)$$

where we have defined the present worth factor:

$$PWF = \sum_{t=1}^N \frac{1}{(1+r)^t} = \frac{1}{r} \left[1 - \frac{1}{(1+r)^N} \right] \quad (3)$$

The LCC is calculated for each class in the year standards are imposed, using a discount rate, r .

4.1.1 LCC Data Inputs

The purchase price is based on the factory costs in the Engineering Analysis (Chapter 1) and includes a factory markup plus distributor and retailer markups, calculated by MIM. Installation and maintenance costs are also from the Engineering Analysis. Purchase price and installation costs are added to the present value of operating expenses (including maintenance, if applicable), discounted, and summed over the life of the product. Expenses in future years are discounted to the year of purchase, 1996. For the residential sector, the discount rate is 6% real, with sensitivity analysis performed at 2% and 10% real.

The energy price is the projected 1996 average residential energy price times an end-use multiplier (see Volume A, Section 5.1.5 of this Technical Support Document), of 1.04 (electric) or 1.20 (gas).

4.1.2 LCC Results

Figures 4.1 through 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 Cost for an Electric Cooktop, Coil Element

Table 4.1 Life-Cycle Costs of Electric Cooktop, Coil Element (Adjusted Usage)

Standard Level	Design No.	Design Option	Install & Maint	Retail Price	Equipment Price	Energy Factor	kWh/yr	Annual Energy Cost	Life-Cycle Costs		
									4%	6%	10%
1	0	Coil	0.00	179.96	179.96	77.2%	271.10	23.34	486.57	440.45	375.24
2	1	0 + Contact	0.00	184.75	184.75	80.5%	260.20	22.41	479.03	434.76	372.18
3,4,5	2	1 + Reflect	0.00	191.20	191.20	81.3%	257.70	22.19	482.66	438.81	376.83

Notes: Average lifetime for all electric cooktops is 19 years.
 All costs are in 1990 dollars.
 Electricity rate is 8.61 cent/kWh (1996).
 Installation costs and maintenance costs are not included in the above calculations.

Figure 4.2 Life-Cycle Cost for an Electric Cooktop, Smooth Element

Table 4.2 Life-Cycle Costs of Electric Cooktop, Smooth Element (Adjusted Usage)

Standard Design Level	Design No.	Design Option	Install & Maint	Retail Price	Equipment Price	Energy Factor	kWh/yr	Annual Energy Cost	Life-Cycle Costs		
									4%	6%	10%
1,2,3	0	Solid	0.00	289.75	289.75	71.3%	293.70	25.29	621.92	571.95	501.31
4	1	0 + Induction	0.00	874.50	874.50	81.0%	258.50	22.26	1166.86	1122.88	1060.70
5	2	0 + Halogen	0.00	636.99	636.99	72.4%	289.20	24.90	964.07	914.87	845.31
	3	0 + Ceramic	0.00	414.70	414.70	68.7%	304.70	26.24	759.31	707.47	634.18

Notes: Average lifetime for all electric cooktops is 19 years.
 All costs are in 1990 dollars.
 Electricity rate is 8.61 cent/kWh (1996).
 Installation costs and maintenance costs are not included in the above calculations.

Figure 4.3 Life-Cycle Cost for a Gas Cooktop

Table 4.3 Life-Cycle Costs of Gas Cooktop (Adjusted Usage)

Standard Design Level	Design No.	Design Option	Install & Maint	Retail Price	Equip-ment Price	Energy Factor	Annual Energy Use		Annual Energy Cost	Life-Cycle Costs		Costs
							Gas (MMBtu)	Elec (kWh)		4%	6%	
	0	Conventional ⁵	0.00	219.91	219.91	18.8%	3.8866	0.0	28.70	596.82	540.12	459.96
1	1	0 + Red Burn Excess Air	0.00	221.54	221.54	19.5%	3.7581	0.0	27.75	585.98	531.16	453.65
2	2	1 + IID	80.91	252.38	333.29	42.9%	1.7083	0.0	12.61	522.07	474.04	408.39
	3	2 + Sealed	80.91	296.20	377.11	45.0%	1.6292	0.0	12.03	558.22	511.34	447.32
3,4,5	4	3 + Reflect	80.91	307.08	387.99	45.0%	1.6274	0.0	12.02	568.92	522.07	458.09
	5	4 + Thermostat	80.91	342.01	422.92	45.0%	1.6274	0.0	12.02	603.85	557.00	493.02

Notes: Average lifetime for all gas cooktops is 19 years.
 All costs are in 1990 dollars.
 Electricity rate is 8.61 cent/kWh (1996).
 Gas rate is 7.384 \$/MMBtu (1996).
 Equipment Prices include maintenance costs (present value at 6% real discount rate).

⁵ Conventional cooktop: 4 burners @9000 Btu/each, no power cord, 2 standing pilots @117 Btu/each.

Figure 4.4 Life-Cycle Cost for an Electric Oven, non Self-cleaning

Table 4.4 Life-Cycle Costs of Electric Oven, Non-Self-Cleaning (Adjusted Usage)

Standard Design Level	Design No.	Design Option	Equip-			Energy Factor kWh/yr	Annual Energy Cost	Life-Cycle Costs		
			Install & Maint	Retail Price	ment Price			4%	6%	10%
	0	Baseline	0.00	395.43	395.43	0.109 327.2	28.18	765.49	709.82	631.12
	1	0 + No Window	0.00	395.43	395.43	0.112 315.9	27.20	752.71	698.96	622.98
	2	1 + Improved Door Seals	0.00	397.96	397.96	0.119 298.7	25.72	735.79	684.97	613.12
	3	2 + Reduced Vent	0.00	401.21	401.21	0.124 287.0	24.71	725.80	676.97	607.94
1	4	3 + Reflective Surface	0.00	404.27	404.27	0.128 278.3	23.96	719.02	671.67	604.74
2	5	4 + Add Insulation	0.00	414.16	414.16	0.138 256.8	22.11	704.60	660.91	599.14
	6	5 + Convection	0.00	431.63	431.63	0.159 223.8	19.27	684.75	646.67	592.84
3,4	7	6 + Reduce Therm. Mass	0.00	436.73	436.73	0.163 217.5	18.73	682.72	645.71	593.40
	8	7 + Improved Insulation	0.00	444.39	444.39	0.168 211.3	18.20	683.37	647.42	596.59
	9	8 + Biradiant Oven	0.00	577.74	577.74	0.220 161.2	13.88	760.06	732.63	693.86
	10	9 + Separator	0.00	603.12	603.12	0.225 157.6	13.57	781.36	754.55	716.64
5	11	10 + Reduce Conduction Loss	0.00	609.23	609.23	0.226 157.3	13.55	787.13	760.37	722.54
	12	0 + Improved Door Seals	0.00	397.96	397.96	0.115 308.6	26.57	746.98	694.48	620.25
	13	12 + Reduced Vent	0.00	401.21	401.21	0.120 296.0	25.49	735.98	685.62	614.42
	14	13 + Reflective Surface	0.00	404.27	404.27	0.124 286.7	24.69	728.52	679.75	610.79
	15	14 + Add Insulation	0.00	414.46	414.46	0.135 263.8	22.72	712.82	667.93	604.48
	16	15 + Convection	0.00	431.63	431.63	0.155 228.8	19.70	690.40	651.47	596.44
	17	16 + Reduce Therm Mass	0.00	436.73	436.73	0.160 222.2	19.13	688.04	650.23	596.79
	18	17 + Improved Insulation	0.00	444.39	444.39	0.165 215.7	18.57	688.34	651.64	599.76
	19	18 + Biradiant Oven	0.00	577.74	577.74	0.217 163.5	14.08	762.66	734.84	695.51
	20	19 + Separator	0.00	603.12	603.12	0.222 159.7	13.75	783.74	756.57	718.16
	21	20 + Reduce Conduction Loss	0.00	609.23	609.23	0.223 159.5	13.73	789.62	762.49	724.12

Notes: Average lifetime for all electric oven is 19 years. All costs are in 1990 dollars.
Electricity rate is 8.61 cent/kWh (1996). Installation costs and maintenance costs are not included in the above calculations.

Figure 4.5 Life-Cycle Cost for an Electric Oven, Self-cleaning

Table 4.5 Life-Cycle Costs of Electric Oven, Self-Cleaning (Adjusted Usage)

Standard Level	Design No.	Design Option	Install & Maint	Retail Price	Equipment Price	Energy Factor	kWh/yr	Annual Energy Cost	Life-Cycle Costs		
									4%	6%	10%
1	0	Baseline	0.00	595.54	595.54	0.102	346.7	29.86	987.65	928.67	845.27
	1	0 + No Window	0.00	595.54	595.54	0.105	336.9	29.01	976.57	919.25	838.22
2	2	1 + Reflective Surface	0.00	600.50	600.50	0.108	328.7	28.31	972.26	916.33	837.27
3	3	2 + Convection	0.00	628.89	628.89	0.124	287.3	24.74	953.82	904.94	835.84
	4	3 + Add Insulation	0.00	642.49	642.49	0.130	273.2	23.53	951.48	904.99	839.28
4	5	4 + Reduce Thermal Mass	0.00	651.05	651.05	0.133	266.8	22.97	952.80	907.40	843.23
	6	5 + Biradiant Oven	0.00	838.83	838.83	0.167	212.7	18.32	1079.39	1043.20	992.04
	7	6 + Separator	0.00	871.78	871.78	0.170	209.4	18.03	1108.61	1072.98	1022.62
5	8	7 + Reduce Conduction Losses	0.00	881.90	881.90	0.170	209.2	18.01	1118.50	1082.91	1032.59
	9	0 + Reflective Surface	0.00	600.50	600.50	0.105	337.8	29.09	982.55	925.07	843.82
10	9	9 + Convection	0.00	628.89	628.89	0.121	293.5	25.27	960.84	910.90	840.30
11	10	10 + Add Insulation	0.00	642.49	642.49	0.127	278.6	23.99	957.58	910.18	843.17
12	11	11 + Reduce Thermal Mass	0.00	651.05	651.05	0.131	271.7	23.40	958.34	912.11	846.76
13	12	12 + Biradiant Oven	0.00	838.83	838.83	0.165	215.0	18.51	1081.99	1045.41	993.70
14	13	13 + Separator	0.00	871.78	871.78	0.168	211.6	18.22	1111.10	1075.10	1024.20
15	14	14 + Reduce Conduction Losses	0.00	881.90	881.90	0.168	211.4	18.20	1120.99	1085.02	1034.18

Notes: Average lifetime for all electric oven is 19 years All costs are in 1990 dollars.
Electricity rate is 8.61 cent/kWh (1996).
Installation costs and maintenance costs are not included in the above calculations.

Figure 4.6 Life-Cycle Cost for a Gas Oven, non Self-cleaning

Table 4.6 Life-Cycle Costs of Gas Oven, Non-Self-Cleaning (Adjusted Usage)

Standard Level	Design No.	Design Option	Install & Maint	Retail Price	Equipment Price	Energy Factor	Annual Energy Use		Annual Energy Cost	Life-Cycle Costs		
							Gas (MMBtu)	Elec (kWh)		4%	6%	10%
	0	Baseline	0.00	450.61	450.61	0.035	3.5801	0.0	26.43	797.79	745.56	671.73
	1	0 + No Window	0.00	450.61	450.61	0.035	3.4994	0.0	25.84	789.97	738.92	666.74
1	2	1 + Electronic Ignition	0.00	464.45	464.45	0.061	1.8869	47.8	18.05	701.49	665.83	615.42
	3	2 + Reduced Vent	0.00	469.19	469.19	0.067	1.6966	47.8	16.64	687.78	654.90	608.41
	4	3 + Improved Door Seals	0.00	472.52	472.52	0.071	1.5881	47.8	15.84	680.59	649.29	605.04
	5	4 + Reflective Surface	0.00	476.73	476.73	0.076	1.4727	47.8	14.99	673.61	643.99	602.12
2	6	5 + Add Insulation	0.00	487.17	487.17	0.090	1.2181	47.8	13.11	659.36	633.45	596.84
	7	6 + Convection	0.00	507.82	507.82	0.103	1.0238	51.9	12.03	665.80	642.04	608.44
	8	7 + Reduce Thermal Mass	0.00	512.64	512.64	0.106	0.9986	51.9	11.84	668.18	644.78	611.70
3,4	9	8 + Improved Insulation	0.00	519.61	519.61	0.109	0.9670	51.9	11.61	672.08	649.15	616.72
	10	9 + Separator	0.00	603.93	603.93	0.115	0.9002	51.9	11.12	749.93	727.96	696.91
5	11	10 + Reduce Conduction Losses	0.00	611.70	611.70	0.116	0.8956	51.9	11.08	757.25	735.35	704.40

Notes: Average lifetime for all gas ovens is 19 years; all costs are in 1990 dollars; electricity rate is 8.61 cent/kWh (1996); gas rate is 7.384 \$/MMBtu (1996); installation costs and maintenance costs are not included in the above calculations.

Figure 4.7 Life-Cycle Cost for a Gas Oven, Self-cleaning

Table 4.7 Life-Cycle Costs of Gas Oven, Self-Cleaning (Adjusted Usage)

Standard Design Level	Design No.	Design Option	Install & Maint	Retail Price	Equipment Price	Energy Factor	Annual Energy Use		Annual Energy Cost	Life-Cycle Costs		
							Gas (MMBtu)	Elec (kWh)		4%	6%	10%
1	0	Baseline	0.00	744.14	744.14	0.058	1.8821	80.3	20.81	1017.48	976.36	918.23
	1	0 + No Window	0.00	744.14	744.14	0.059	1.8151	80.3	20.32	1010.98	970.84	914.09
2	2	1 + Improved Door Seals	0.00	748.41	748.41	0.063	1.7094	80.3	19.54	1005.00	966.40	911.83
3	3	2 + Reflective Surface	0.00	753.39	753.39	0.066	1.6160	80.3	18.85	1000.92	963.68	911.04
4	4	3 + Add Insulation	0.00	771.40	771.40	0.074	1.4052	80.3	17.29	998.49	964.33	916.03
	5	4 + Reduce Thermal Mass	0.00	778.87	778.87	0.076	1.3652	80.3	16.99	1002.08	968.50	921.03
5	6	5 + Convection	0.00	812.72	812.72	0.084	1.1816	84.5	16.00	1022.88	991.26	946.57
	7	6 + Reduce Conduction Losses	0.00	827.36	827.36	0.085	1.1772	84.5	15.97	1037.09	1005.54	960.93
5	8	7 + Separator	0.00	1003.29	1003.29	0.087	1.1323	84.5	15.64	1208.66	1177.77	1134.09
	9	0 + Improved Door Seals	0.00	748.41	748.41	0.061	1.7681	80.3	19.97	1010.69	971.23	915.46
10	9	1 + Reflective Surface	0.00	753.39	753.39	0.064	1.6678	80.3	19.23	1005.94	967.95	914.24
	11	10 + Add Insulation	0.00	771.40	771.40	0.072	1.4431	80.3	17.57	1002.16	967.45	918.37
12	11	10 + Reduce Thermal Mass	0.00	778.87	778.87	0.074	1.4007	80.3	17.26	1005.52	971.43	923.22
	12	11 + Convection	0.00	812.72	812.72	0.083	1.2079	84.5	16.20	1025.43	993.43	948.19
14	13	12 + Reduce Conduction Losses	0.00	827.36	827.36	0.083	1.2032	84.5	16.16	1039.61	1007.68	962.54
	15	14 + Separator	0.00	1003.29	1003.29	0.086	1.1561	84.5	15.81	1210.97	1179.73	1135.56

Notes: Same notes as in Table 4.6 apply.

Figure 4.8 Life-Cycle Cost for a Microwave Oven

Table 4.8 Life-Cycle Costs of Microwave Ovens (Metered Energy Data)

Standard Design Level	Design No.	Design Option	Install & Maint	Retail Price	Equipment Price	Energy Factor	kWh/yr	Annual Energy Cost	Life-Cycle Costs		
									4%	6%	10%
	0	Baseline	0.00	185.98	185.98	54.0%	270.00	23.25	374.56	357.10	328.84
1	1	0 + More Efficient Power Supply	0.00	191.47	191.47	61.0%	239.00	20.58	358.40	342.95	317.93
2	2	1 + More Efficient Fan	0.00	192.76	192.76	61.8%	236.00	20.32	357.59	342.33	317.63
3	3	2 + Modify Wave Guide	0.00	195.12	195.12	62.5%	233.30	20.09	358.07	342.98	318.56
4	4	3 + Improved Magnetron	0.00	211.36	211.36	63.4%	230.00	19.81	372.00	357.13	333.06
5	5	4 + Reflective Surfaces	0.00	232.78	232.78	63.9%	228.20	19.65	392.17	377.41	353.53

Notes: Average lifetime for all microwave ovens is 10 years.
All costs are in 1990 dollars.
Electricity rate is 8.61 cent/kWh (1996).
Installation costs and maintenance costs are not included in the above calculations.

4.2 PAYBACK PERIODS BY STANDARD LEVEL

The payback period (PBP) measures the amount of time needed to recover the additional consumer investment in increased efficiency through lower operating costs. Payback period is found by solving the equation:

$$\Delta PC + \sum_{t=1}^{PAY} \Delta OC_t = 0 \quad (4)$$

for *PAY*. In general, *PAY* is found by interpolating between the two years when the expression in Eq .4 changes sign. If the operating cost is constant, the equation has the simple solution:

$$PAY = -\frac{\Delta PC}{\Delta OC} \quad (5)$$

Numerically, the payback period is the ratio of the increase in purchase (and installation) price from the base to the standards 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.

4.2.1 PBP Data Inputs

The data inputs are the same as in Section 4.1.1, except that in addition, a distribution of design options is projected (by LBL-REM) in the base case. Only those designs that are eliminated by the standard level are included in the calculation of impacts. Consumers whose base case choice is eliminated by standards are assumed to purchase the design option corresponding to the minimum compliance with the standard.

4.2.2 PBP Results

The PBPs by standard level shown in Tables 4.9 through 4.16 are the weighted averages. They compare that portion of the projected distribution of designs in the base case that are less efficient than the standard level to the design at the standard level. Designs with energy consumption at or below the standard level are not affected by the standard, so these are excluded from the calculation of impacts.

Table 4.9 shows the calculation of LCC differences, payback, and CCE. The table is composed of several parts. Table 4.9.a summarizes the equipment cost, operating cost, LCC, and energy use for each design option. Table 4.9.b shows the distribution of units sold in 1996, according to the base case forecast. In the other columns, part of this distribution is expressed as the percent of eliminated units due to standards. That is, if 78% of units sold in the base case correspond to design 0, and standard level 1 (equivalent to design 1) eliminates only design 0, then the fraction of eliminated units due to standard level 1 is 100% for design 0.

Table 4.9.c applies the weights in Table 4.9.b to the values in Table 4.9.a to obtain the weighted average values shown. Table 4.9.d shows the resulting LCC differences, PBPs, and CCE.

4.3 CHANGE IN LIFE-CYCLE COSTS DUE TO STANDARDS

The impact of standards is calculated as the difference in LCC, base case minus standards case. If the LCC difference is greater than zero (positive savings), the standard 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 standard causes a net increase in expenses to the consumer.

4.3.1 Data Inputs for Change in LCC

The data inputs are the same as in Section 4.1.1, except that in addition, a distribution of design options is projected (by LBL-REM) in the base case. Only those designs that are eliminated by the standard level are included in the calculation of impacts. Consumers whose base case choice is eliminated by standards are assumed to purchase the design option corresponding the minimum compliance with the standard.

4.3.2 Results for Change in LCC

Tables 4.9 through 4.16 show the LCC differences by standard 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 standard level to the design at the standard level. Designs with energy consumption at or below the standard level are not affected by the standard, so these are excluded from the calculation of impacts. These LCCs are calculated at a 6% discount rate; a higher discount rate (e.g., 10%) gives a smaller difference.

Tables 4.9.d to 4.16.d show lower LCC (positive LCC difference) for virtually all standard levels for all classes. The cases that demonstrate a higher LCC (negative LCC difference) include the following: (1) standard level 5 for all classes except electric cooktops, coil element, and gas cooktops and (2) standard level 4 for only the electric cooktop, smooth element class.

4.4 COST OF CONSERVED ENERGY (CCE) DUE TO STANDARDS

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:

$$CCE = -\frac{CRF \cdot \Delta PC}{\Delta E}, \quad (6)$$

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.

4.4.1 CCE Data Inputs

The data inputs are the same as in Section 4.1.1, except that in addition, a distribution of design options is projected (by LBL-REM) in the base case. Only those designs that are eliminated by the standard level are included in the calculation of impacts. Consumers whose base case choice is eliminated by standards are assumed to purchase the design option corresponding to the minimum compliance with the standard.

4.4.2 CCE Results

Tables 4.9 through 4.16 show the cost of conserved energy at the site of the standards levels as compared to the base case. Note that the current (1990) and projected (1996) average residential electricity prices are 8.11 and 8.29 cents per kWh, respectively (58). These are equivalent to 23.74 to and 24.28 dollars per million Btu, respectively, where one kWh is taken as 3,412 Btu of site energy. The residential price of natural gas was \$5.69 per million Btu in 1990 and is projected to be \$6.15 in 1996 (1).

Standard levels with CCEs less than projected costs of energy supply include:

- Electric Cooktops, Coil Element: Standard Levels 2 through 5.
- Gas Cooktops: Standard Levels 1 and 2.
- Electric Ovens, Non-Self-Cleaning: Standard Levels 1 through 4.
- Electric Ovens, Self-Cleaning: Standard Levels 2 through 4.
- Gas Ovens, Non-Self-Cleaning: Standard Levels 1 through 4.
- Gas Ovens, Self-Cleaning: Standard Levels 2 and 3.
- Microwave Ovens: Standard Levels 1 through 3.

Standard levels with CCEs greater than projected costs of energy supply include:

Electric Cooktops, Smooth Element: Standard Levels 4 and 5.

Gas Cooktops: Standard Levels 3 through 5.

Electric Ovens, Non-Self-Cleaning: Standard Level 5.

Electric Ovens, Self-Cleaning: Standard Level 5.

Gas Ovens, Non-Self-Cleaning: Standard Level 5.

Gas Ovens, Self-Cleaning: Standard Levels 4 and 5.

Microwave Ovens: Standard Levels 4 and 5.

Table 4.9.a Cost and Energy Use Summary, Electric Cooktop, Coil Element

Design Number	Equipment Price	Operating Cost	LCC	Annual Energy Use	
	(1990 \$)	(1990 \$)	(1990 \$)	(kWh)	(MMBtu)
0	179.96	23.34	440.45	271	0.92
1	184.75	22.41	434.76	260	0.89
2	191.20	22.19	438.81	258	0.88

Table 4.9.b Distribution of Units Sold Below Standards, Electric Cooktop, Coil Element

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
0	100.00%<Standard>		100.00%	100.00%	100.00%	100.00%
1	0.00%		<Standard>	0.00%	0.00%	0.00%
2	0.00%			<Standard>	<Standard>	<Standard>

Table 4.9.c Weighted-Averages of Units Sold Below Standards, Electric Cooktop, Coil Element

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
Equip. Price (1990 \$)	NA	179.96	179.96	179.96	179.96
Operating Cost (1990 \$)	NA	23.34	23.34	23.34	23.34
Life-Cycle Cost (1990 \$)	NA	440.45	440.45	440.45	440.45
Energy Use (MMBtu/yr)	NA	0.92	0.92	0.92	0.92

Table 4.9.d Life-Cycle Cost Differences (\$1990), Payback Periods (Year), and Costs of Conserved Energy (at 6% Real), Electric Cooktop, Coil Element

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
LCC difference	NA	5.7	1.6	1.6	1.6
Payback	NA	5.2	9.8	9.8	9.8
CCE (cent/kWH)	NA	3.9	7.5	7.5	7.5
CCE (\$/MMBtu)	NA	11.5	22.0	22.0	22.0

Table 4.10.a Cost and Energy Use Summary, Electric Cooktop, Smooth Element

Design Number	Equipment Price (1990 \$)	Operating Cost (1990 \$)	LCC (1990 \$)	Annual Energy Use	
				(kWh)	(MMBtu)
0	289.75	25.29	571.95	294	1.00
2	636.99	24.90	914.87	289	0.99
1	874.50	22.26	1122.88	258	0.88

Table 4.10.b Distribution of Units Sold Below Standards, Electric Cooktop, Smooth Element

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
0	99.77% <Standard>	<Standard>	<Standard>		100.00%	99.77%
2	0.23%				<Standard>	0.23%
1	0.00%					<Standard>

Table 4.10.c Weighted-Averages of Units Sold Below Standards, Electric Cooktop, Smooth Element

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
Equip. Price (1990 \$)	NA	NA	NA	289.75	290.55
Operating Cost (1990 \$)	NA	NA	NA	25.29	25.29
Life-Cycle Cost (1990 \$)	NA	NA	NA	571.95	572.74
Energy Use (MMBtu/yr)	NA	NA	NA	1.00	1.00

Table 4.10.d Life-Cycle Cost Differences (\$1990), Payback Periods (Year) and Costs of Conserved Energy (at 6% Real), Electric Cooktop, Smooth Element

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
LCC difference	NA	NA	NA	-342.9	-550.1
Payback	NA	NA	NA	890.4	192.8
CCE (cent/kWH)	NA	NA	NA	691.7	148.7
CCE (\$/MMBtu)	NA	NA	NA	2027.4	435.9

Table 4.11.a Cost and Energy Use Summary, Gas Cooktop

Design Number	Equipment Price (1990 \$)	Operating Cost (1990 \$)	LCC (1990 \$)	Annual Energy Use (MMBtu)
0	219.91	28.70	540.12	3.89
1	221.54	27.75	531.16	3.76
2	333.29	12.61	474.04	1.71
3	377.11	12.03	511.34	1.63
4	387.99	12.02	522.07	1.63

Table 4.11.b Distribution of Units Sold Below Standards, Gas Cooktop

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
0	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
1	0.00%<Standard>		0.00%	0.00%	0.00%	0.00%
2	0.00%		<Standard>	0.00%	0.00%	0.00%
3	0.00%			0.00%	0.00%	0.00%
4	0.00%			<Standard>	<Standard>	<Standard>

Table 4.11.c Weighted-Averages of Units Sold Below Standards, Gas Cooktop

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
Equip. Price (1990 \$)	219.91	219.91	219.91	219.91	219.91
Operating Cost (1990 \$)	28.70	28.70	28.70	28.70	28.70
Life-Cycle Cost (1990 \$)	540.12	540.12	540.12	540.12	540.12
Energy Use (MMBtu/yr)	3.89	3.89	3.89	3.89	3.89

Table 4.11.d Life-Cycle Cost Differences (\$1990), Payback Periods (Year), and Costs of Conserved Energy (at 6% Real), Gas Cooktop

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
LCC difference	9.0	66.1	18.0	18.0	18.0
Payback	1.7	7.0	10.1	10.1	10.1
CCE (\$/MMBtu)	1.1	4.7	6.7	6.7	6.7

Table 4.12.a Cost and Energy Use Summary, Electric Oven, Non-Self-Cleaning

Design Number	Equipment Price	Operating Cost	LCC	Annual Energy Use	
	(1990 \$)	(1990 \$)	(1990 \$)	(kWh)	(MMBtu)
0	395.43	28.18	709.82	327	1.12
1	395.43	27.20	698.96	316	1.08
2	397.96	25.72	684.97	299	1.02
3	401.21	24.71	676.97	287	0.98
4	404.27	23.96	671.67	278	0.95
5	414.16	22.11	660.91	257	0.88
6	431.63	19.27	646.67	224	0.76
7	436.73	18.73	645.71	218	0.74
8	444.39	18.20	647.42	211	0.72
9	577.74	13.88	732.63	161	0.55
10	603.12	13.57	754.55	158	0.54
11	609.23	13.55	760.37	157	0.54

Table 4.12.b Distribution of Units Sold Below Standards, Electric Oven, Non-Self-Cleaning

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
4	0.00%	<Standard>	0.00%	0.00%	0.00%	0.00%
5	0.00%		<Standard>	0.00%	0.00%	0.00%
6	0.00%			0.00%	0.00%	0.00%
7	0.00%			<Standard>	<Standard>	0.00%
8	0.00%					0.00%
9	0.00%					0.00%
10	0.00%					0.00%
11	0.00%					<Standard>

Table 4.12.c Weighted-Averages of Units Sold Below Standards, Electric Oven Non-Self-Cleaning

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
Equip. Price (1990 \$)	395.43	395.43	395.43	395.43	395.43
Operating Cost (1990 \$)	27.20	27.20	27.20	27.20	27.20
Life-Cycle Cost (1990 \$)	698.96	698.96	698.96	698.96	698.96
Energy Use (MMBtu/yr)	1.08	1.08	1.08	1.08	1.08

Table 4.12.d Life-Cycle Cost Differences (\$1990), Payback Periods (Year), and Costs of Conserved Energy (at 6% Real), Electric Oven, Non-Self-Cleaning

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
LCC difference	27.3	38.1	53.3	53.3	-61.4
Payback	2.7	3.7	4.9	4.9	15.7
CCE (cent/kWh)	2.1	2.8	3.8	3.8	12.1
CCE (\$/MMBtu)	6.2	8.3	11.0	11.0	35.4

Table 4.13.a Cost and Energy Use Summary, Electric Oven, Self-Cleaning

Design Number	Equipment Price (1990 \$)	Operating Cost (1990 \$)	LCC (1990 \$)	Annual Energy Use	
				(kWh)	(MMBtu)
0	595.54	29.86	928.67	347	1.18
1	595.54	29.01	919.25	337	1.15
2	600.50	28.31	916.33	329	1.12
3	628.89	24.74	904.94	287	0.98
4	642.49	23.53	904.99	273	0.93
5	651.05	22.97	907.40	267	0.91
6	838.83	18.32	1043.20	213	0.73
7	871.78	18.03	1072.98	209	0.71
8	881.90	18.01	1082.91	209	0.71

Table 4.13.b Distribution of Units Sold Below Standards, Electric Oven, Self-Cleaning

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
0	0.00%	<Standard>	0.00%	0.00%	0.00%	0.00%
1	100.00%		100.00%	100.00%	100.00%	100.00%
2	0.00%		<Standard>	0.00%	0.00%	0.00%
3	0.00%			<Standard>	0.00%	0.00%
4	0.00%				0.00%	0.00%
5	0.00%				<Standard>	0.00%
6	0.00%					0.00%
7	0.00%					0.00%
8	0.00%					<Standard>

Table 4.13.c Weighted-Averages of Units Sold Below Standards, Electric Oven, Self-Cleaning

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
Equip. Price (1990 \$)	NA	595.54	595.54	595.54	595.54
Operating Cost (1990 \$)	NA	29.01	29.01	29.01	29.01
Life-Cycle Cost (1990 \$)	NA	919.25	919.25	919.25	919.25
Energy Use (MMBtu/yr)	NA	1.15	1.15	1.15	1.15

Table 4.13.d Life-Cycle Cost Differences (\$1990), Payback Periods (Year), and Costs of Conserved Energy (at 6% Real), Electric Oven, Self-Cleaning

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
LCC difference	NA	2.9	14.3	11.9	-163.7
Payback	NA	7.1	7.8	9.2	26.0
CCE (cent/kWH)	NA	5.4	6.0	7.1	20.1
CCE (\$/MMBtu)	NA	15.9	17.7	20.8	58.9

Table 4.14.a Cost and Energy Use Summary, Gas Oven, Non-Self-Cleaning

Design Number	Equipment Price	Operating Cost	LCC	Annual Energy Use
	(1990 \$)	(1990 \$)	(1990 \$)	(MMBtu)
0	450.61	26.43	745.56	3.58
1	450.61	25.84	738.92	3.50
2	464.45	18.05	665.83	2.05
3	469.19	16.64	654.90	1.86
4	472.52	15.84	649.29	1.75
5	476.73	14.99	643.99	1.64
6	487.17	13.11	633.45	1.38
7	507.82	12.03	642.04	1.20
8	512.64	11.84	644.78	1.18
9	519.61	11.61	649.15	1.14
10	603.93	11.12	727.96	1.08
11	611.70	11.08	735.35	1.07

Table 4.14.b Distribution of Units Sold Below Standards, as Oven, Non-Self-Cleaning

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1	28.43%	100.00%	28.43%	28.43%	28.43%	28.43%
2	8.47%	<Standard>	8.47%	8.47%	8.47%	8.47%
3	0.00%		0.00%	0.00%	0.00%	0.00%
4	50.87%		50.87%	50.87%	50.87%	50.87%
5	12.23%		12.23%	12.23%	12.23%	12.23%
6	0.00%		<Standard>	0.00%	0.00%	0.00%
7	0.00%			0.00%	0.00%	0.00%
8	0.00%			0.00%	0.00%	0.00%
9	0.00%			0.00%	0.00%	0.00%
10	0.00%			<Standard>	<Standard>	0.00%
11	0.00%					<Standard>

Table 4.14.c Weighted-Averages of Units Sold Below Standards, Gas Oven, Non Self-Cleaning

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
Equip. Price (1990 \$)	450.61	466.12	466.12	466.12	466.12
Operating Cost (1990 \$)	25.84	18.77	18.77	18.77	18.77
Life-Cycle Cost (1990 \$)	738.92	675.52	675.52	675.52	675.52
Energy Use (MMBtu/yr)	3.50	2.26	2.26	2.26	2.26

Table 4.14.d Life-Cycle Cost Differences (\$1990), Payback Periods (Year), and Costs of Conserved Energy (at 6% Real), Gas Oven, Non-Self-Cleaning

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
LCC difference	73.1	42.1	26.4	26.4	-59.8
Payback	1.8	3.7	7.5	7.5	18.9
CCE (\$/MMBtu)	0.9	2.1	4.3	4.3	11.0

Table 4.15.a Cost and Energy Use Summary Gas Oven, Self-Cleaning

Design Number	Equipment Price (1990 \$)	Operating Cost (1990 \$)	LCC (1990 \$)	Annual Energy Use (MMBtu)
0	744.14	20.81	976.36	2.16
1	744.14	20.32	970.84	2.09
2	748.41	19.54	966.40	1.98
3	753.39	18.85	963.68	1.89
4	771.40	17.29	964.33	1.68
5	778.87	16.99	968.50	1.64
6	812.72	16.00	991.26	1.47
7	827.36	15.97	1005.54	1.47
8	1003.29	15.64	1177.77	1.42

Table 4.15.b Distribution of Units Sold Below Standards, Gas Oven, Self-Cleaning

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
0	0.00%	<Standard>	0.00%	0.00%	0.00%	0.00%
1	100.00%		100.00%	100.00%	100.00%	100.00%
2	0.00%		<Standard>	0.00%	0.00%	0.00%
3	0.00%			<Standard>	0.00%	0.00%
4	0.00%				0.00%	0.00%
5	0.00%				<Standard>	0.00%
6	0.00%					0.00%
7	0.00%					0.00%
8	0.00%					<Standard>

Table 4.15.c Weighted-Averages of Units Sold Below Standards, Gas Oven, Self-Cleaning

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
Equip. Price (1990 \$)	NA	744.14	744.14	744.14	744.14
Operating Cost (1990 \$)	NA	20.32	20.32	20.32	20.32
Life-Cycle Cost (1990 \$)	NA	970.84	970.84	970.84	970.84
Energy Use (MMBtu/yr)	NA	2.09	2.09	2.09	2.09

Table 4.15.d Life-Cycle Cost Differences (\$1990), Payback Periods (Year), and Costs of Conserved Energy (at 6% Real), Gas Oven, Self-Cleaning

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
LCC difference	NA	4.4	7.2	2.3	-206.9
Payback	NA	5.5	6.3	10.4	55.4
CCE (\$/MMBtu)	NA	3.6	4.2	6.9	34.8

Table 4.16.a Cost and Energy Use Summary, Microwave Oven

Design Number	Equipment Price (1990 \$)	Operating Cost (1990 \$)	LCC (1990 \$)	Annual Energy Use (kWh)	(MMBtu)
0	185.98	23.25	357.10	270	0.92
1	191.47	20.58	342.95	239	0.82
2	192.76	20.32	342.33	236	0.81
3	195.12	20.09	342.98	233	0.80
4	211.36	19.81	357.13	230	0.78
5	232.78	19.65	377.41	228	0.78

Table 4.16.b Distribution of Units Sold Below Standards, Microwave Oven

Design Number	1996 Distribution	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
0	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
1	0.00%	<Standard>	0.00%	0.00%	0.00%	0.00%
2	0.00%		<Standard>	0.00%	0.00%	0.00%
3	0.00%			<Standard>	0.00%	0.00%
4	0.00%				<Standard>	0.00%
5	0.00%					<Standard>

Table 4.16.c Weighted-Averages of Units Sold Below Standards, Microwave Oven

Weighted Average	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
Equip. Price (1990 \$)	185.98	185.98	185.98	185.98	185.98
Operating Cost (1990 \$)	23.25	23.25	23.25	23.25	23.25
Life-Cycle Cost (1990 \$)	357.10	357.10	357.10	357.10	357.10
Energy Use (MMBtu/yr)	0.92	0.92	0.92	0.92	0.92

Table 4.16.d Life-Cycle Cost Differences (\$1990), Payback Periods (Year), and Costs of Conserved Energy (at 6% Real), Microwave Oven

	Trial Standard Level 1	Trial Standard Level 2	Trial Standard Level 3	Trial Standard Level 4	Trial Standard Level 5
LCC difference	14.1	14.8	14.1	0.0	-20.3
Payback	2.1	2.3	2.9	7.4	13.0
CCE (cent/kWH)	2.4	2.7	3.4	8.6	15.2
CCE (\$/MMBtu)	7.1	7.9	9.9	25.3	44.6

4.5 LCC SENSITIVITY ANALYSIS

The sensitivity of the national LCC results were tested by varying assumptions about energy prices and equipment prices. These tables 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. Projected (1992) state energy prices (59) relative to the national average were applied to the projected 1996 national average price from the *Annual Energy Outlook 1991* to obtain state prices for 1996. (This represents a wider range of prices than analyzed in previous analyses, which used 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 4.9 through 4.13 and Tables 4.17 through 4.21 summarize the results of the sensitivity analysis. These include:

- a graph of highest and lowest LCC sensitivity, and reference case, and
- a table of LCCs for all sensitivity cases. The table also shows the number of sensitivity cases for which each design option is the minimum LCC.

Figure 4.9 Sensitivity Analysis for an Electric Cooktop, Coil Element

Table 4.17 Sensitivity Summary of Life-Cycle Costs of Electric Cooktops (Coil Element)

Standard Level Design Option	1 0	2 1	3,4,5 2	Std Level @ min LCC	Design Option @min LCC
Reference	440	435	439	2	1
1	323	322	327	2	1
2	494	490	497	2	1
3	377	378	385	1	0
4	563	553	556	2	1
5	386	379	381	2	1
6	509	497	498	2	1
# of cases as min LCC	1	6			

Figure 4.10 Sensitivity Analysis for a Gas Cooktop

Table 4.18 Sensitivity Summary of Life-Cycle Costs of Gas Cooktops

Standard Level	1	2	3,4,5		Std Level @	Design Option
Design Option	0	1	2	3	4	min LCC @min LCC
Reference	540	531	474	511	522	2 2
1	444	438	432	471	482	2 2
2	562	553	498	544	561	2 2
3	466	460	456	504	520	2 2
4	1056	1030	701	728	738	2 2
5	518	509	450	479	483	2 2
6	1034	1008	677	695	700	2 2
# of cases as min LCC	7					

Figure 4.11 Sensitivity Analysis for a non Self-cleaning Electric Oven

Table 4.19 Sensitivity Summary of Life Cycle-Costs of Non-Self-Cleaning Electric Ovens

Standard Level													Std Level @ Design Option	
Design Option	0	1	2	3	4	5	6	7	8	9	10	11	min LCC	@ min LCC
Reference	710	699	685	677	672	661	647	646	647	733	755	760	3,4	7
1	568	562	556	553	551	550	550	551	556	663	686	692	2	5
2	789	778	765	760	756	750	745	747	752	904	939	948		6
3	647	641	635	635	635	639	648	652	660	834	870	880		2
4	858	842	821	807	798	777	748	744	743	806	826	832		8
5	631	620	605	594	587	572	549	545	543	561	571	573		8
6	779	763	741	725	714	688	650	644	639	634	642	644		9
# of cases as min LCC			2			1	1	1	2	1				

Figure 4.12 Sensitivity Analysis for a non Self-cleaning Gas Oven

Table 4.20 Sensitivity Summary of Life-Cycle Costs of Non-Self-Cleaning Gas Ovens

Standard Level	1			2			3,4			5			Std Level @ Design Option	
Design Option	0	1	2	3	4	5	6	7	8	9	10	11	min LCC	@ min LCC
Reference	746	739	666	655	649	644	633	642	645	649	728	735	2	6
1	657	652	633	626	623	621	617	631	635	640	720	728	2	6
2	858	852	779	773	768	765	759	778	784	791	946	958	2	6
3	769	765	746	744	742	742	743	768	774	782	938	950		5
4	1221	1204	932	896	876	855	811	795	794	794	864	871		8
5	633	626	552	537	531	523	507	506	506	507	510	513		7
6	1108	1091	819	778	757	734	685	659	655	652	646	649		10
# of cases as min LCC						1	3	1	1		1			

Figure 4.13 Sensitivity Analysis for a Microwave Oven

Table 4.21 Sensitivity Summary of Life-Cycle Costs of Microwave Ovens

Standard Level	1	2	3	4	5	Std Level @	Design Option
Design Option	0	1	2	3	4	min LCC	@ min LCC
Reference	357	343	342	343	357	2	2
1	280	275	275	276	291	1	1
2	394	381	381	382	399	2	2
3	317	313	313	315	334	1	1
4	438	414	413	413	426	3	3
5	320	305	304	304	315	2	2
6	401	376	374	374	384	3	3
# of cases as min LCC	2	3	2				

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

5.1 LONG-RUN IMPACTS

Cooktops and Ovens

The analysis shows that compared to the 1996 base case, the kitchen range and oven industry is likely to experience a return on equity (ROE) decrease at trial standards levels 1 and 2 and a ROE increase at levels 3 through 5. At standards level 1, there is approximately a 73% chance that ROE will decrease, with an expected decrease of 0.05%. At standards level 2 there is approximately a 72% chance of a decrease in ROE, with an expected decrease of 0.19%. At standards level 3 there is approximately a 54% chance of an increase in ROE, with an expected decrease of 0.05%. At standards level 4 there is approximately a 61% chance of an increase in ROE, with an expected increase of 0.27%. At standards level 5 there is approximately a 58% chance of an increase in ROE, with an expected increase of 0.75%. These results are based on 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.

Microwave Ovens

The analysis shows that compared to the 1996 base case, at trial standards levels 1 to 3, the microwave oven industry is likely to experience a ROE decrease. At standards level 4 and 5, the industry is likely to experience a ROE increase. At standards level 1, there is approximately a 54% chance that ROE will decrease, with an expected decrease of 0.05%. At standards level 2 there is approximately a 53% chance of a decrease in ROE, with an expected decrease of 0.05%. At standards level 3 there is approximately a 54% chance of a decrease in ROE, with an expected decrease of 0.05%. At standards level 4 there is approximately a 52% chance of an increase in ROE, with an expected decrease of 0.03%. At standards level 5 there is approximately a 54% chance of an increase in ROE, with an expected decrease of 0.14%. These results are based on 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.

5.1.1 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 standards level considered, these 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 standards are imposed, and to the extent that standards induce an increase in variable costs, such costs will be more than completely passed on in the form of a price increase, which in itself is profitable, but which also tends to reduce profit because of the effect of a price increase on sales. If standards induce 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.) The model calculates that these effects, when combined, are more likely to reduce economic profits than increase them at all standards levels, particularly at standards level 4.

5.1.2 Quantitative analysis

Tables 5.1 and 5.2 summarize all essential outputs from the LBL-MIM simulations using the long-run primary scenario for kitchen ranges and ovens. Six other scenarios are summarized and discussed in the sensitivity section, Section 5.4.

Once the above interpretations are understood, the results of the model concerning the long-run impact of standards on the kitchen range and oven and microwave ovens manufacturing industries can be read from the output table.

Table 5.1 Kitchen Ranges and Ovens: Primary Scenario - Long-Run

	1996 BASE	Level 1	Level 2	Level 3	Level 4	Level 5
Shipments (in Mil)	1.03	1.03	1.04	1.03	1.02	1.00
% change		0.13%	0.60%	-0.21%	-0.86%	-3.52%
S.E.		0.64%	2.97%	4.19%	5.00%	5.62%
Price	\$310.12	\$311.89	\$322.16	\$345.55	\$362.20	\$430.92
% change		0.57%	3.88%	11.42%	16.79%	38.95%
S.E.		0.47%	3.70%	9.55%	14.35%	25.68%
Revenue (in \$M)	\$320.23	\$322.47	\$334.61	\$356.06	\$370.84	\$429.31
% change		0.70%	4.49%	11.19%	15.81%	34.06%
S.E.		1.19%	8.35%	13.98%	16.48%	25.13%
Net Income (in \$M)	\$17.05	\$17.02	\$16.79	\$17.18	\$17.57	\$18.23
Difference		-0.03	-0.26	0.13	0.52	1.18
S.E.		0.02	0.13	0.19	0.31	0.45
ROE	8.63%	8.60%	8.44%	8.68%	8.90%	9.38%
Difference		-0.03%	-0.19%	0.05%	0.27%	0.75%
S.E.		0.04%	0.32%	0.56%	0.94%	1.59%

Table 5.2. Microwave Oven Output Table: Primary Scenario - Long-Run

	1996 BASE	Level 1	Level 2	Level 3	Level 4	Level 5
Shipments (in Mil)	0.77	0.79	0.79	0.79	0.75	0.71
% change		2.39%	2.38%	1.97%	-2.67%	-8.44%
S.E.		12.88%	13.69%	13.94%	34.01%	17.93%
Price	\$151.20	\$156.00	\$157.06	\$158.98	\$171.88	\$188.85
% change		3.18%	3.88%	5.14%	13.68%	24.90%
S.E.		1.09%	1.30%	1.58%	4.52%	8.12%
Revenue (in \$M)	116.48	123.05	123.88	124.89	128.89	133.22
% change		5.64%	6.35%	7.21%	10.65%	14.36%
S.E.		13.20%	14.07%	14.36%	36.70%	21.56%
Net Income (in \$M)	4.92	5.01	5.01	5.02	4.85	4.62
Difference		0.09	0.09	0.10	-0.08	-0.30
S.E.		0.20	0.22	0.21	0.45	0.26
ROE	8.64%	8.59%	8.59%	8.59%	8.67%	8.78%
Difference		-0.05%	-0.05%	-0.05%	0.03%	0.14%
S.E.		0.53%	0.69%	0.49%	0.79%	1.52%

5.2 SHORT-RUN IMPACTS

The business cycle presents the kitchen range and oven and microwave oven manufacturing industries with fairly sharp periodic fluctuations in demand, much larger than the fluctuations predicted for any of the standards levels. These normal demand fluctuations present the same types of opportunities for price competition that will accompany fluctuations resulting from a change in standards. 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 Volume A, Chapter 3, Section 3.3.4.2, and is used to produce a short-run version of the output tables that are displayed in Tables 5.3 and 5.4.

Table 5.3 Kitchen Ranges and Ovens: Primary Scenario - Short-Run

	1996 BASE	Level 1	Level 2	Level 3	Level 4	Level 5
Shipments (in Mil)	1.03	1.03	1.04	1.03	1.02	1.00
% change		0.13%	0.58%	-0.21%	-0.84%	-3.41%
Price	\$310.12	\$311.98	\$322.50	\$345.46	\$361.68	\$428.65
% change		0.60%	3.99%	11.40%	16.63%	38.22%
Revenue (in \$M)	\$320.23	\$322.56	\$334.91	\$355.99	\$370.40	\$427.55
% change		0.73%	4.59%	11.17%	15.67%	33.52%
Net Income (in \$M)	\$17.05	\$17.08	\$17.10	\$17.04	\$16.94	\$15.94
Difference		0.03	0.04	-0.02	-0.12	-1.11
ROE	8.63%	8.63%	8.53%	8.59%	8.59%	8.26%
Difference		0.00%	-0.09%	-0.04%	-0.04%	-0.37%

Table 5.4 Microwave Oven: Primary Scenario - Short-Run

	1996 BASE	Level 1	Level 2	Level 3	Level 4	Level 5
Shipments (in Mil)	0.77	0.79	0.79	0.78	0.75	0.71
% change		2.17%	2.16%	1.78%	-2.39%	-7.49%
Price	\$151.20	\$156.53	\$157.59	\$159.42	\$171.24	\$186.63
% change		3.53%	4.23%	5.44%	13.25%	23.43%
Revenue (in \$M)	116.48	123.21	124.03	125.01	128.76	133.01
% change		5.77%	6.48%	7.32%	10.54%	14.19%
Net Income (in \$M)	4.92	5.27	5.27	5.15	4.47	3.58
Difference		0.35	0.35	0.23	-0.46	-1.35
ROE	8.64%	9.04%	9.04%	8.81%	7.99%	6.80%
Difference		0.40%	0.40%	0.17%	-0.65%	-1.84%
S.E.		2.76%	3.11%	3.13%	2.97%	4.66%

5.3 IMPACT AS A FUNCTION OF FIRM SIZE

Firms in the cooktops and ovens industry may be divided into two groups: those that compete on large sales volume products and those that compete in small, specialized markets. Small firms are generally forced to specialize in small-market niches that offer some protection from the cost advantage that large firms hold when they can produce in volume (e.g., induction cooktops or combined sealed burner and electronic ignition gas cooktops). This effect can even be observed among the major producers in the tendency of the smaller major producers to make somewhat more specialized products (e.g., Jenn-Air). This is not so true for microwave ovens, which tend to resemble products such as televisions more than major appliances such as ranges and ovens.

From our work on other appliances, we find that average cost tends to decrease with increasing firm size. Thus, 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. The fact that the consolidation has been producing larger firms strongly corroborates the finding that large firms have a cost advantage. The nature of microwave oven manufacturing has resulted in heavy domination by foreign conglomerates (again, similar to televisions). The Industry Profile section (Volume A, Chapter 4) discusses these issues in greater detail.

A principal implication of consolidation is that the smaller of the major firms will be, on average, in more danger of failing or being bought out than will the larger firms. Because of the greater precariousness 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.

Most, if not all, of the standards levels considered do not require any significant retooling of plant and equipment. This factor, taken with the above, implies that there will probably not be significant adverse impacts on small firms.

5.4 SENSITIVITY ANALYSIS FOR KITCHEN RANGES AND OVENS

5.4.1 Sensitivity Charts

The three following subsections discuss different aspects of the sensitivity analysis conducted by LBL-MIM. This first subsection, on sensitivity charts, shows the implications of the uncertainty of each control variable for the prediction of ROE. The next subsection shows six alternative scenarios that are of particular importance and deserve a more detailed analysis than those randomly generated by Monte Carlo runs. The last subsection shows the use of Monte Carlo runs to find combinations of errors that would cause the change in ROE to be considerably more negative than is predicted.

Tables 5.5 to 5.7 list the sensitivities of ROE to a change in control panel inputs. The variables analyzed are industry price elasticity of demand (IPE), discount rate (RD), the equity cost of capital (ECC), economic profit (EP), the fixed part of costs (FCA), the fixed part of one-time costs (FIX), one-time capital costs (CC.N), one-time variable costs (dVC.N), and the shape parameter of the demand curve (ro.N).

Table 5.5 Cooktops Sensitivity Charts: Sensitivity of a Change in 1 S.E. in Control Variables

Control Variables			Possible Standards Levels				
Name	Value	Changed	1	2	3	4	5
IPE	-0.150	-0.345	0.01%	0.17%	-0.07%	-0.35%	-0.55%
RD	36.79%	84.59%	0.03%	0.56%	0.87%	1.16%	1.37%
ECC	0.068	0.075	0.00%	0.00%	0.00%	-0.01%	-0.01%
EP	0.018	0.028	0.00%	-0.06%	0.02%	0.10%	0.15%
FCA	0.088	0.142	-0.02%	-0.26%	0.11%	0.54%	0.82%
FIX	0.059	0.102	0.00%	0.00%	-0.01%	-0.04%	-0.06%
CC.N	0.000	0.000	0.00%	0.00%	0.00%	-0.02%	-0.03%
dVC.N	0.336	0.450	0.01%	0.16%	0.41%	0.67%	0.85%
ro.N	0.000	0.300	0.02%	0.23%	-0.10%	-0.50%	-0.77%

Table 5.6 Ovens Sensitivity Charts: Sensitivity of a Change in 1 S.E. in Control Variables

Control Variables			Possible Standards Levels				
Name	Value	Changed	1	2	3	4	5
IPE	-0.150	-0.345	0.00%	0.01%	0.00%	0.00%	-0.12%
RD	37.48%	86.17%	0.03%	0.06%	0.12%	0.13%	0.29%
ECC	0.068	0.075	0.00%	0.00%	0.00%	0.00%	-0.01%
EP	0.018	0.028	-0.01%	-0.01%	0.00%	0.00%	0.18%
FCA	0.017	0.027	-0.01%	-0.01%	0.00%	0.01%	0.18%
FIX	0.057	0.100	0.00%	-0.01%	-0.01%	-0.02%	-0.09%
CC.N	0.166	0.203	0.00%	0.00%	0.00%	-0.01%	-0.03%
dVC.N	2.226	2.985	0.01%	0.02%	0.07%	0.08%	0.31%
ro.N	0.000	0.300	0.01%	0.02%	0.00%	-0.01%	-0.27%

Table 5.7 Microwave Ovens Sensitivity Charts: Sensitivity of a Change in 1 S.E. in Control Variables

Control Variables			Possible Standards Levels				
Name	Value	Changed	1	2	3	4	5
IPE	-0.600	-1.380	0.16%	0.16%	0.14%	-0.21%	-0.77%
RD	250.00%	574.80%	0.05%	0.06%	0.07%	0.18%	0.33%
ECC	0.068	0.075	0.00%	0.00%	0.00%	0.00%	0.00%
EP	0.018	0.028	-0.02%	-0.02%	-0.03%	0.02%	0.09%
FCA	0.040	0.064	0.00%	0.00%	0.00%	0.00%	0.01%
FIX	0.042	0.073	0.00%	0.00%	-0.01%	0.00%	0.00%
CC.N	0.000	0.000	0.00%	0.00%	0.00%	0.00%	-0.01%
dVC.N	5.000	6.706	0.01%	0.02%	0.02%	0.05%	0.09%
ro.N	0.000	0.300	0.10%	0.10%	0.08%	-0.12%	-0.43%

As can be seen from the tables, four 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 discount rate (RD) from which operating-cost elasticity is derived, (3) fixed part of costs (FCA), one-time variable costs (dVC.N), and (4) the shape parameter of the demand curve (ro.N). The reasons that these variables are important are discussed below.

5.4.2 Alternative Scenarios

The sensitivity analysis shows that both price and operating-cost elasticities (the latter being derived from the discount rate) play crucial roles in determining the model's output. These are both *industry* elasticities as opposed to single-firm elasticities; this means they measure the effect on demand of a change in price by all firms and a change in operating cost of all kitchen ranges and ovens (and microwave ovens). The estimates of standard errors that 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, six alternative scenarios have been run. The six scenarios include low and high price elasticity scenarios, a constant shipments scenario (i.e., industry price and operating-cost elasticity set to zero), high and low discount rate scenarios (i.e., high and low operating-cost scenarios), and a low discount rate and high price-elasticity scenario. Tables 5.8 through 5.13 show the results of running these six scenarios for the kitchen range and ovens manufacturing industry.

In these alternative scenarios, note the impact of a change in the discount rate. A high RD input value lowers ROE and a lower RD value increases ROE. Because markup is determined by price elasticity, it will tend to change as the ratio of price to operating cost changes. Standards will always increase this ratio, which decreases markup. This effect will be the strongest when appliance demand is relatively elastic with respect to operating cost. That is, a more elastic operating-cost elasticity will result in a greater decrease in markup under standards, resulting in a greater decrease in profitability.

The other tables show that increasing price-elasticity also tends to lower ROE. This effect is probably due to the greater decline in shipments when price-elasticity is greater.

The percentage of fixed costs (FCA) is important because of its role in the model. It determines the LBL-MIM's estimate of the markup over variable cost, which, in turn, determines the firm's ability to pass on various combinations of fixed and variable costs. For a more detailed explanation, see Appendix C of Volume A.

The shape of the demand curve parameter (ro.N) plays a role under certain circumstances. The demand function is specified as a function of life-cycle cost (i.e., of purchase price and operating cost). If purchase price plays a relatively large role in the demand function, then demand is less sensitive to changes in the shape parameter since in the limit, demand would be a function of purchase price. Hence the shape parameter plays a larger role when operating cost and price play relatively equal roles in determining life-cycle cost. Also, it depends on how much of a change in operating costs result from a particular standards level under consideration. This is because a large change in operating cost will shift demand to a very different part of the demand curve.

The incremental variable cost (dVC.L) is important because of its impact on price and because it is a variable cost. Firms will pass on increases in variable costs in the form of higher prices; therefore, profitability is affected by the amount of variable cost increase that can be

passed on. As noted in Appendix C of Volume A, variable costs are passed on, while fixed costs are not, so variable costs in general do not hurt profitability. Further, as increased variable costs are translated into higher prices, price-elasticity and markup are affected, and a change in markup affects profitability.

5.4.3 Monte Carlo Analysis

The Monte Carlo approach is described in Volume A, Chapter 3, Section 3.3.4.3, and the standard errors it generates are reported in the output tables. More detail of a Monte Carlo run can be seen on Tables 5.14 and 5.15. These tables show the control panels from two Monte Carlo runs, which were selected because they show a decrease in long-run ROE. Both Monte Carlo runs were done on standards level 2. In the first run, we see how large increases in price-elasticity coupled with increases in the percentage of both fixed costs and one-time costs (which are not passed through via prices) and the discount rate are the primary factors in reducing ROE. In the second, increases in price-elasticity and one-time costs with a smaller increase in the discount rate reduce ROE despite a small decrease in fixed costs.

Table 5.8 Kitchen Ranges and Ovens Output Table: Low Price-Elasticity Scenario

	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	1.03	1.03	1.03	1.03	1.03	1.03
% change		0.00%	0.00%	0.00%	0.00%	0.00%
S.E.		0.00%	0.00%	0.00%	0.00%	0.00%
Price	\$310.12	\$311.89	\$322.16	\$345.56	\$362.20	\$430.92
% change		0.57%	3.88%	11.43%	16.79%	38.95%
S.E.		0.43%	3.53%	9.11%	13.65%	24.20%
Revenue (in \$M)	\$319.64	\$321.47	\$332.05	\$356.17	\$373.32	\$444.15
% change		0.57%	3.88%	11.43%	16.79%	38.95%
S.E.		0.61%	8.14%	23.11%	37.40%	55.53%
Net Income (in \$M)	17.04	16.97	16.6	17.24	17.89	19.25
Difference		-0.07	-0.44	0.2	0.85	2.21
S.E.		0.05	0.35	0.49	0.86	1.99
ROE	8.63%	8.59%	8.39%	8.69%	8.99%	9.57%
Difference		-0.03%	-0.23%	0.07%	0.35%	0.94%
S.E.		0.02%	0.18%	0.24%	0.42%	0.97%

Table 5.9 Kitchen Ranges and Ovens Output Table: High Price-Elasticity Scenario

	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	1.04	1.04	1.04	1.03	1.03	0.98
% change		0.21%	0.36%	-0.08%	-0.18%	-4.68%
S.E.		0.07%	0.19%	0.48%	0.54%	1.75%
Price	\$310.12	\$311.89	\$322.16	\$345.56	\$362.20	\$430.92
% change		0.57%	3.88%	11.43%	16.79%	38.95%
S.E.		0.45%	3.57%	9.04%	13.66%	24.98%
Revenue (in \$M)	\$321.78	\$323.62	\$334.27	\$356.17	\$373.32	\$423.34
% change		0.57%	3.88%	10.69%	16.02%	31.56%
S.E.		0.35%	3.29%	8.26%	12.77%	20.62%
Net Income (in \$M)	17.07	17.04	16.7	17.24	17.88	18.19
Difference		-0.03	-0.37	0.17	0.81	1.12
S.E.		0.04	0.37	0.43	0.92	2.15
ROE	8.63%	8.60%	8.41%	8.70%	8.98%	9.44%
Difference		-0.03%	-0.23%	0.07%	0.35%	0.81%
S.E.		0.02%	0.20%	0.24%	0.48%	1.13%

Table 5.10 Kitchen Ranges and Ovens Output Table: Constant Shipments Scenario

	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	1.03	1.03	1.03	1.03	1.03	1.03
% change		0.00%	0.00%	0.00%	0.00%	0.00%
S.E.		0.00%	0.00%	0.00%	0.00%	0.00%
Price	\$310.12	\$311.89	\$322.16	\$345.56	\$362.20	\$430.92
% change		0.57%	3.88%	11.43%	16.79%	38.95%
S.E.		0.44%	3.47%	8.84%	15.42%	24.85%
Revenue (in \$M)	\$319.64	\$321.47	\$332.05	\$356.17	\$373.32	\$444.15
% change		0.57%	3.88%	11.43%	16.79%	38.95%
S.E.		0.44%	3.47%	8.84%	15.42%	24.85%
Net Income (in \$M)	17.04	16.97	16.6	17.24	17.89	19.25
Difference		-0.07	-0.44	0.2	0.85	2.21
S.E.		0.03	0.32	0.5	1.08	2.22
ROE	8.63%	8.59%	8.39%	8.69%	8.99%	9.57%
Difference		-0.03%	-0.23%	0.07%	0.35%	0.94%
S.E.		0.02%	0.16%	0.25%	0.53%	1.09%

Table 5.11 Microwave Oven Output Table: High Price-Elasticity Scenario

	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	0.77	0.81	0.81	0.80	0.73	0.65
% change		4.83%	4.81%	3.98%	-5.26%	-16.16%
S.E.		1.30%	1.70%	2.13%	4.65%	6.22%
Price	\$151.20	\$156.00	\$157.06	\$158.98	\$171.88	\$188.85
% change		3.18%	3.88%	5.14%	13.68%	24.90%
S.E.		1.01%	1.33%	1.70%	4.34%	7.06%
Revenue (in \$M)	116.48	125.99	126.82	127.35	125.45	121.98
% change		8.16%	8.87%	9.32%	7.70%	4.71%
S.E.		0.30%	0.40%	0.52%	1.33%	2.35%
Net Income (in \$M)	4.92	5.20	5.20	5.18	4.63	3.96
Difference		0.28	0.28	0.26	-0.29	-0.96
S.E.		0.13	0.15	0.16	0.33	0.59
ROE	8.64%	8.72%	8.72%	8.70%	8.51%	8.19%
Difference		0.08%	0.08%	0.06%	-0.13%	-0.45%
S.E.		0.19%	0.19%	0.16%	0.40%	0.97%

Table 5.12 Microwave Oven Output Table: Low Price-Elasticity Scenario

	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	0.77	0.77	0.77	0.77	0.77	0.77
% 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	\$156.00	\$157.06	\$158.98	\$171.88	\$188.85
% change		3.18%	3.88%	5.14%	13.68%	24.90%
S.E.		1.08%	1.25%	1.62%	4.11%	8.00%
Revenue (in \$M)	116.48	120.18	121.00	122.48	132.42	145.49
% change		3.18%	3.88%	5.14%	13.68%	24.90%
S.E.		1.08%	1.25%	1.62%	4.11%	7.99%
Net Income (in \$M)	4.92	4.82	4.82	4.86	5.07	5.35
Difference		-0.10	-0.10	-0.06	0.14	0.42
S.E.		0.06	0.06	0.08	0.14	0.35
ROE	8.64%	8.46%	8.46%	8.47%	8.83%	9.32%
Difference		-0.18%	-0.18%	-0.17%	0.19%	0.68%
S.E.		0.11%	0.11%	0.14%	0.24%	0.61%

Table 5.13 Microwave Oven Output Table: Constant Shipments Scenario

	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	0.77	0.77	0.77	0.77	0.77	0.77
% 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	\$156.00	\$157.06	\$158.98	\$171.88	\$188.85
% change		3.18%	3.88%	5.14%	13.68%	24.90%
S.E.		1.16%	1.36%	1.57%	4.19%	7.93%
Revenue (in \$M)	116.48	120.18	121.00	122.48	132.42	145.49
% change		3.18%	3.88%	5.14%	13.68%	24.90%
S.E.		1.16%	1.36%	1.57%	4.19%	7.93%
Net Income (in \$M)	4.92	4.82	4.82	4.86	5.07	5.35
Difference		-0.10	-0.10	-0.06	0.14	0.42
S.E.		0.06	0.07	0.07	0.18	0.37
ROE	8.64%	8.46%	8.46%	8.47%	8.83%	9.32%
Difference		-0.18%	-0.18%	-0.17%	0.19%	0.68%
S.E.		0.11%	0.12%	0.13%	0.31%	0.64%

Table 5.14 Cooktops Monte Carlo Runs: Searching for Low ROE

		Scenario: Primary		Standard Level = 2		
COOKTOPS		Input		Vari-	Progrm	
CONTROL FACTORS		Value	Cntrl	ation	Value	Name
Price-Elasticity		-0.150	-0.78	100%	-0.079	IPE
Consumer Discount Rate		36.79%	-2.51	100%	4.53%	RD
Equity Cost of Capital		0.068	0.56	10%	0.072	ECC
Economic Profit		0.018	0.38	1%	0.022	EP
L-R Fixed Part of Costs & Assets		0.088	-0.27	50%	0.078	FCA
L-R Fixed Part of 1-X Cap. Cost		0.071	-0.26	60%	0.061	F1X
One-Time Capital Costs		0.162	-0.38	20%	0.150	CC.N
Unit Variable Cost Increase		\$7.74	0.72	30%	9.555	dVC.N
Elasticity Curve Parameter		0.000	-0.86	30%	-0.257	ro.N
Short Run Price Response to Demand		0.157	0.39	76%	0.265	SRPR
	NAECA	NEW		PRVIOUS	NEW	
SUMMARY	BASE	L-RUN	CHANGE	CHANGE	S-RUN	
Shipments	1.01	1.13	11.98%	-0.56%	1.12	
Price	\$99.01	\$105.89	6.95%	20.64%	\$109.17	
Revenue (in \$M)	99.68	119.38	19.76%	19.96%	122.75	
Net Income	5.81	5.11	-0.70	0.11	7.51	
ROE	9.41%	7.41%	-2.00%	0.19%	10.89%	
08-Sep-92		22:38	Trys =		51.00	
		Scenario: Primary		Standard Level = 2		
COOKTOPS (COM)		Input		Vari-	Progrm	
CONTROL FACTORS		Value	Cntrl	ation	Value	Name
Price-Elasticity		-0.150	-0.58	100%	-0.092	IPE
Consumer Discount Rate		36.79%	-1.11	100%	14.66%	RD
Equity Cost of Capital		0.068	-0.86	10%	0.062	ECC
Economic Profit		0.018	0.11	1%	0.019	EP
L-R Fixed Part of Costs & Assets		0.088	0.55	50%	0.114	FCA
L-R Fixed Part of 1-X Cap. Cost		0.071	1.07	60%	0.128	F1X
One-Time Capital Costs		0.162	0.53	20%	0.180	CC.N
Unit Variable Cost Increase		\$7.74	-0.75	30%	6.210	dVC.N
Elasticity Curve Parameter		0.000	-1.81	30%	-0.544	ro.N
Short Run Price Response to Demand		0.157	0.98	76%	0.574	SRPR
	NAECA	NEW		PRVIOUS	NEW	
SUMMARY	BASE	L-RUN	CHANGE	CHANGE	S-RUN	
Shipments	1.01	1.05	3.97%	1.36%	1.04	
Price	\$99.01	\$102.16	3.17%	7.26%	\$104.36	
Revenue (in \$M)	99.68	106.93	7.27%	8.72%	109.01	
Net Income	5.05	3.41	-1.64	-0.23	4.90	
ROE	8.19%	5.33%	-2.86%	-0.49%	7.65%	
Operating Cost Elasticity	-0.14					
08-Sep-92		22:38	Trys =		14.00	

Table 5.15 Microwave Oven Monte Carlo Runs: Searching for Low ROE

MICROWAVE OVENS CONTROL FACTORS		Input Value	Cntrl	Vari- ation	Progrm Value	Name
Price-Elasticity		-0.600	2.16	100%	-3.612	IPE
Consumer Discount Rate		250.00%	1.03	100%	590.84%	RD
Equity Cost of Capital		0.068	0.71	10%	0.073	ECC
Economic Profit		0.018	2.38	1%	0.042	EP
L-R Fixed Part of Costs & Assets		0.040	1.17	50%	0.070	FCA
L-R Fixed Part of 1-X Cap. Cost		0.027	-1.24	60%	0.014	FIX
One-Time Capital Costs		1.780	-0.07	20%	1.757	CC.N
Unit Variable Cost Increase		\$7.56	2.13	30%	14.149	dVC.N
Elasticity Curve Parameter		0.000	0.10	30%	0.029	ro.N
Short Run Price Response to Demand		0.157	0.10	76%	0.180	SRPR
SUMMARY		NAECA BASE	NEW L-RUN	PRVIOUS CHANGE	NEW S-RUN	
Shipments		0.77	0.61	-20.60%	1.97%	0.69
Price		\$151.20	\$166.41	10.06%	5.14%	\$163.15
Revenue (in \$M)		116.48	101.80	-12.61%	7.21%	112.01
Net Income		6.56	4.36	-2.20	0.10	4.02
ROE		11.52%	9.50%	-2.01%	-0.05%	8.75%
Operating Cost Elasticity		-32.82				
08-Sep-92		22:34		Trys =	1284.00	
MICROWAVE OVENS CONTROL FACTORS		Input Value	Cntrl	Vari- ation	Progrm Value	Name
Price-Elasticity		-0.600	2.57	100%	-5.080	IPE
Consumer Discount Rate		250.00%	1.05	100%	597.98%	RD
Equity Cost of Capital		0.068	0.15	10%	0.069	ECC
Economic Profit		0.018	0.34	1%	0.022	EP
L-R Fixed Part of Costs & Assets		0.040	0.93	50%	0.062	FCA
L-R Fixed Part of 1-X Cap. Cost		0.027	0.67	60%	0.040	FIX
One-Time Capital Costs		1.780	0.87	20%	2.115	CC.N
Unit Variable Cost Increase		\$7.56	2.28	30%	14.781	dVC.N
Elasticity Curve Parameter		0.000	1.93	30%	0.579	ro.N
Short Run Price Response to Demand		0.157	-1.19	76%	0.032	SRPR
SUMMARY		NAECA BASE	NEW L-RUN	PRVIOUS CHANGE	NEW S-RUN	
Shipments		0.77	0.57	-25.57%	1.97%	0.61
Price		\$151.20	\$164.64	8.89%	5.14%	\$163.55
Revenue (in \$M)		116.48	94.40	-18.96%	7.21%	100.02
Net Income		5.18	1.92	-3.26	0.10	1.85
ROE		9.09%	4.45%	-4.64%	-0.05%	4.27%
Operating Cost Elasticity		-46.71				
08-Sep-92		22:19		Trys =	229.00	

CHAPTER 6. IMPACTS OF STANDARDS ON ELECTRIC UTILITIES: OVENS, COOKTOPS, AND MICROWAVE OVENS

6.1 INTRODUCTION

Appliance efficiency standards 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 standard levels. The fourth section presents the results of the revenue loss calculation. More details on methodology may be found in Appendix E of Volume A.

6.2 AVOIDED ENERGY AND AVOIDED RELIABILITY COSTS

Figure 6.1 shows avoided energy and reliability costs for electricity savings from cooking equipment. These figures show the sum of avoided costs for the base-, high-, and low-energy-price cases.⁶ The value per million Btu (MMBtu) of avoided reliability costs is the same in all three energy-price cases. The avoided fuel and capital component depends on fuel prices and varies among the three cases. As explained in Appendix E of Volume A, this component implicitly contains the costs avoided when baseload power plants are deferred or canceled (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. They are used in the LBL-REM to value electricity savings from the societal perspective.

6.3 PEAK LOAD AND CAPACITY REDUCTIONS

Tables 6.1 to 6.3 show peak load reductions for ovens, cooktops, and microwaves for the relevant standard levels. Tables 6.4 to 6.6 show capacity savings for ovens, cooktops, and microwaves for the relevant standard levels. The base case peak load in the second column of Tables 6.1 through 6.3 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

⁶ Fuel price forecasts for the period 1990 to 2000 are taken from the DOE/EIA *Annual Energy Outlook 1991* (DOE/EIA-0383(91)). The forecasts for years after 2000 were linearly extrapolated using the methodology described in Volume A. The high (low) energy price case is derived by increasing (decreasing) the reference case AEO fuel price forecasts for gas and coal by 5%.

load factors, a T&D loss factor of 1.075, and estimates of energy consumption calculated using the LBL-REM. Capacity savings are peak-load savings in regions that need additional capacity, multiplied by 1.2 to account for reserve margin needed for adequate reliability. The amount of capacity saved can be somewhat less than the peak-demand savings in years before 1999 because capacity savings are only counted in regions that need capacity. After 1998, capacity savings consistently exceed peak-load savings by the reserve margin of 20% (numbers may not exactly correspond to this rule because of rounding errors).

Peak-demand reductions from the standards for ovens range from 0.1 to 0.5 GW in 2000, and from 0.1 to 1.6 GW in 2030. Capacity savings for ovens range from 0.1 to 0.7 GW in 2000, and from 0.2 to 2.0 GW in 2030.

Peak-demand changes from the standards for cooktops range from an increase of 0.1 to a decrease of 0.1 GW in 2000, and from an increase of 0.3 to a decrease of 0.4 GW in 2030. Capacity savings for cooktops range from an increase of 0.2 to a decrease of 0.1 GW in 2000, and from an increase of 0.3 to a decrease of 0.5 GW in 2030.

Peak-demand reductions from the standards for microwaves range from 0.4 to 0.6 GW in 2000, and from 0 to 0.3 GW in 2030. Capacity savings for microwaves range from 0.5 to 0.7 GW in 2000, and from 0 to 0.3 GW in 2030.

Figure 6.1 Utility-Avoided Costs for Kitchen Ranges and Ovens

Table 6.1 Peak Demand Reductions (GW) - Ovens

Year	Peak Load	Peak Demand Savings				
		Level 1	Level 2	Level 3	Level 4	Level 5
1996	5.9	0.0	0.0	0.1	0.1	0.2
1997	5.5	0.0	0.0	0.1	0.2	0.3
1998	5.2	0.0	0.1	0.2	0.2	0.4
1999	5.1	0.1	0.1	0.2	0.3	0.5
2000	5.1	0.1	0.1	0.2	0.3	0.5
2001	5.1	0.1	0.1	0.3	0.4	0.6
2002	5.1	0.1	0.1	0.3	0.4	0.7
2003	5.2	0.1	0.2	0.4	0.5	0.8
2004	5.2	0.1	0.2	0.4	0.5	0.9
2005	5.2	0.1	0.2	0.5	0.6	1.0
2006	5.2	0.1	0.2	0.5	0.6	1.1
2007	5.3	0.1	0.2	0.6	0.7	1.2
2008	5.3	0.2	0.2	0.6	0.7	1.3
2009	5.3	0.2	0.3	0.6	0.8	1.4
2010	5.3	0.2	0.3	0.7	0.8	1.4
2011	5.4	0.2	0.3	0.7	0.8	1.5
2012	5.4	0.2	0.3	0.7	0.9	1.6
2013	5.4	0.2	0.3	0.7	0.9	1.6
2014	5.4	0.2	0.3	0.7	0.9	1.6
2015	5.5	0.2	0.3	0.7	0.9	1.6
2016	5.5	0.2	0.3	0.7	0.9	1.6
2017	5.5	0.2	0.3	0.7	0.9	1.6
2018	5.5	0.2	0.3	0.7	0.9	1.6
2019	5.5	0.2	0.3	0.7	0.9	1.6
2020	5.5	0.2	0.3	0.7	0.9	1.6
2021	5.6	0.2	0.3	0.7	0.9	1.6
2022	5.6	0.1	0.3	0.7	0.9	1.6
2023	5.6	0.1	0.3	0.7	0.9	1.6
2024	5.6	0.1	0.3	0.7	0.9	1.6
2025	5.6	0.1	0.2	0.7	0.9	1.6
2026	5.7	0.1	0.2	0.7	0.9	1.6
2027	5.7	0.1	0.2	0.7	0.9	1.6
2028	5.7	0.1	0.2	0.7	0.9	1.6
2029	5.7	0.1	0.2	0.7	0.9	1.6
2030	5.8	0.1	0.2	0.7	0.9	1.6

Table 6.2 Peak Demand Reductions (GW) - Cooktops

Year	Peak Load	Peak Demand Savings			
		Level 1	Level 2	Level 3	Level 4
1996	5.3	0.0	0.0	0.0	0.1
1997	4.9	0.0	0.0	0.0	0.1
1998	4.7	0.0	0.0	-0.1	0.1
1999	4.5	0.0	-0.1	-0.1	0.1
2000	4.5	0.0	-0.1	-0.1	0.1
2001	4.5	0.0	-0.1	-0.1	0.1
2002	4.6	0.0	-0.1	-0.2	0.2
2003	4.6	0.0	-0.1	-0.2	0.2
2004	4.7	0.0	-0.1	-0.2	0.2
2005	4.7	0.0	-0.1	-0.2	0.2
2006	4.7	0.0	-0.1	-0.2	0.3
2007	4.8	0.0	-0.1	-0.2	0.3
2008	4.8	0.0	-0.1	-0.2	0.3
2009	4.8	0.0	-0.1	-0.2	0.3
2010	4.9	0.0	-0.2	-0.2	0.4
2011	4.9	0.0	-0.2	-0.2	0.4
2012	4.9	0.0	-0.2	-0.2	0.4
2013	4.9	0.0	-0.2	-0.2	0.4
2014	4.9	0.0	-0.2	-0.2	0.4
2015	5.0	0.0	-0.2	-0.2	0.4
2016	5.0	0.0	-0.2	-0.2	0.4
2017	5.0	0.0	-0.2	-0.2	0.4
2018	5.0	0.0	-0.2	-0.2	0.5
2019	5.0	0.0	-0.2	-0.2	0.5
2020	5.1	0.0	-0.2	-0.3	0.4
2021	5.1	0.0	-0.2	-0.3	0.4
2022	5.1	0.0	-0.2	-0.3	0.4
2023	5.1	0.0	-0.2	-0.3	0.4
2024	5.2	0.0	-0.2	-0.3	0.4
2025	5.2	0.0	-0.2	-0.3	0.4
2026	5.2	0.0	-0.2	-0.3	0.4
2027	5.2	0.0	-0.2	-0.3	0.4
2028	5.3	0.0	-0.2	-0.3	0.4
2029	5.3	0.0	-0.2	-0.3	0.4
2030	5.3	0.0	-0.2	-0.3	0.4

Table 6.3 Peak Demand Reductions (GW) - Microwaves

Year	Peak Load	Peak Demand Savings				
		Level 1	Level 2	Level 3	Level 4	Level 5
1996	5.5	0.2	0.2	0.2	0.3	0.3
1997	5.7	0.2	0.3	0.3	0.3	0.4
1998	5.8	0.3	0.3	0.4	0.4	0.4
1999	6.0	0.4	0.4	0.5	0.5	0.5
2000	6.1	0.4	0.5	0.5	0.6	0.6
2001	6.2	0.5	0.6	0.6	0.7	0.7
2002	6.4	0.5	0.6	0.7	0.7	0.8
2003	6.5	0.6	0.7	0.7	0.8	0.8
2004	6.6	0.6	0.7	0.8	0.8	0.9
2005	6.7	0.7	0.7	0.8	0.8	0.9
2006	6.8	0.7	0.7	0.8	0.9	0.9
2007	6.9	0.7	0.7	0.8	0.9	0.9
2008	6.9	0.7	0.7	0.8	0.9	0.9
2009	7.0	0.7	0.8	0.8	0.9	0.9
2010	7.0	0.6	0.7	0.8	0.8	0.9
2011	7.0	0.5	0.6	0.7	0.8	0.8
2012	7.0	0.5	0.5	0.6	0.7	0.7
2013	6.9	0.4	0.5	0.5	0.6	0.7
2014	6.9	0.3	0.4	0.5	0.5	0.6
2015	6.9	0.3	0.3	0.4	0.5	0.5
2016	6.9	0.2	0.3	0.3	0.4	0.5
2017	6.9	0.1	0.2	0.3	0.3	0.4
2018	6.9	0.1	0.1	0.2	0.3	0.3
2019	6.9	0.0	0.1	0.2	0.3	0.3
2020	6.9	0.0	0.1	0.1	0.2	0.3
2021	7.0	0.0	0.1	0.1	0.2	0.3
2022	7.0	0.0	0.1	0.1	0.2	0.3
2023	7.1	0.0	0.1	0.1	0.2	0.3
2024	7.1	0.0	0.1	0.1	0.2	0.3
2025	7.2	0.0	0.1	0.1	0.2	0.3
2026	7.2	0.0	0.1	0.1	0.2	0.3
2027	7.3	0.0	0.1	0.1	0.2	0.3
2028	7.3	0.0	0.1	0.2	0.2	0.3
2029	7.4	0.0	0.1	0.2	0.2	0.3
2030	7.5	0.0	0.1	0.2	0.2	0.3

Table 6.4 Capacity Savings (GW) - Ovens

Year	Capacity Savings				
	Level 1	Level 2	Level 3	Level 4	Level 5
1996	0.0	0.0	0.1	0.1	0.1
1997	0.0	0.0	0.1	0.1	0.2
1998	0.0	0.0	0.1	0.1	0.3
1999	0.1	0.1	0.2	0.3	0.5
2000	0.1	0.1	0.3	0.4	0.7
2001	0.1	0.1	0.3	0.4	0.8
2002	0.1	0.2	0.4	0.5	0.9
2003	0.1	0.2	0.4	0.5	1.0
2004	0.1	0.2	0.5	0.6	1.1
2005	0.1	0.2	0.6	0.7	1.2
2006	0.2	0.3	0.6	0.7	1.3
2007	0.2	0.3	0.7	0.8	1.4
2008	0.2	0.3	0.7	0.9	1.5
2009	0.2	0.3	0.8	0.9	1.7
2010	0.2	0.3	0.8	1.0	1.7
2011	0.2	0.3	0.8	1.0	1.8
2012	0.2	0.4	0.9	1.0	1.9
2013	0.2	0.4	0.9	1.1	1.9
2014	0.2	0.4	0.9	1.1	1.9
2015	0.2	0.4	0.9	1.1	1.9
2016	0.2	0.3	0.9	1.1	1.9
2017	0.2	0.3	0.9	1.1	1.9
2018	0.2	0.3	0.9	1.1	1.9
2019	0.2	0.3	0.9	1.1	1.9
2020	0.2	0.3	0.9	1.1	1.9
2021	0.2	0.3	0.9	1.1	1.9
2022	0.2	0.3	0.9	1.1	1.9
2023	0.2	0.3	0.9	1.1	1.9
2024	0.2	0.3	0.9	1.1	1.9
2025	0.2	0.3	0.9	1.1	1.9
2026	0.2	0.3	0.9	1.1	1.9
2027	0.2	0.3	0.9	1.1	1.9
2028	0.2	0.3	0.9	1.1	1.9
2029	0.2	0.3	0.9	1.1	1.9
2030	0.2	0.3	0.9	1.1	2.0

Table 6.5 Capacity Savings (GW) -Cooktops

Year	Capacity Savings			
	Level 1	Level 2	Level 3	Level 4
1996	0.0	0.0	0.0	0.0
1997	0.0	0.0	0.0	0.1
1998	0.0	0.0	-0.1	0.1
1999	0.0	-0.1	-0.1	0.1
2000	0.0	-0.1	-0.2	0.1
2001	0.0	-0.1	-0.2	0.2
2002	0.0	-0.1	-0.2	0.2
2003	0.0	-0.1	-0.2	0.2
2004	0.0	-0.2	-0.2	0.3
2005	0.0	-0.2	-0.2	0.3
2006	0.0	-0.2	-0.2	0.3
2007	0.0	-0.2	-0.2	0.4
2008	0.0	-0.2	-0.3	0.4
2009	0.0	-0.2	-0.3	0.4
2010	0.0	-0.2	-0.3	0.5
2011	0.0	-0.2	-0.3	0.5
2012	0.0	-0.2	-0.3	0.5
2013	0.0	-0.2	-0.3	0.5
2014	0.0	-0.2	-0.3	0.5
2015	0.0	-0.2	-0.3	0.5
2016	0.0	-0.2	-0.3	0.5
2017	0.0	-0.2	-0.3	0.5
2018	0.0	-0.2	-0.3	0.5
2019	0.0	-0.2	-0.3	0.5
2020	0.0	-0.2	-0.3	0.5
2021	0.0	-0.2	-0.3	0.5
2022	0.0	-0.2	-0.3	0.5
2023	0.0	-0.2	-0.3	0.5
2024	0.0	-0.2	-0.3	0.5
2025	0.0	-0.3	-0.3	0.5
2026	0.0	-0.3	-0.4	0.5
2027	0.0	-0.3	-0.4	0.5
2028	0.0	-0.3	-0.4	0.5
2029	0.0	-0.3	-0.4	0.5
2030	0.0	-0.2	-0.3	0.5

Table 6.6 Capacity Savings (GW) - Microwaves

Year	Capacity Savings				
	Level 1	Level 2	Level 3	Level 4	Level 5
1996	0.1	0.1	0.2	0.2	0.2
1997	0.2	0.2	0.2	0.2	0.3
1998	0.2	0.2	0.3	0.3	0.3
1999	0.4	0.5	0.5	0.6	0.6
2000	0.5	0.6	0.6	0.7	0.7
2001	0.6	0.7	0.7	0.8	0.8
2002	0.7	0.7	0.8	0.9	0.9
2003	0.7	0.8	0.9	0.9	1.0
2004	0.8	0.8	0.9	1.0	1.0
2005	0.8	0.9	0.9	1.0	1.1
2006	0.8	0.9	0.9	1.0	1.1
2007	0.8	0.9	1.0	1.0	1.1
2008	0.8	0.9	1.0	1.1	1.1
2009	0.8	0.9	1.0	1.1	1.1
2010	0.7	0.8	0.9	1.0	1.0
2011	0.7	0.7	0.8	0.9	1.0
2012	0.6	0.7	0.7	0.8	0.9
2013	0.5	0.6	0.6	0.7	0.8
2014	0.4	0.5	0.6	0.7	0.7
2015	0.3	0.4	0.5	0.6	0.6
2016	0.2	0.3	0.4	0.5	0.5
2017	0.2	0.2	0.3	0.4	0.5
2018	0.1	0.2	0.3	0.4	0.4
2019	0.0	0.1	0.2	0.3	0.4
2020	0.0	0.1	0.2	0.3	0.3
2021	0.0	0.1	0.2	0.3	0.3
2022	0.0	0.1	0.2	0.3	0.3
2023	0.0	0.1	0.2	0.3	0.3
2024	0.0	0.1	0.2	0.3	0.3
2025	0.0	0.1	0.2	0.3	0.3
2026	0.0	0.1	0.2	0.3	0.3
2027	0.0	0.1	0.2	0.3	0.3
2028	0.0	0.1	0.2	0.3	0.3
2029	0.0	0.1	0.2	0.3	0.3
2030	0.0	0.1	0.2	0.3	0.3

6.4 REVENUE LOSSES

Appliance standards allow utilities to avoid the variable costs of generating electricity, but standards also reduce electricity sales. In a 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 standards 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, use the most current information on the impacts of appliance efficiency standards.

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 standards 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 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 standards, 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 standards 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-standard sales forecast, this case is included as an absolute upper bound. Figure 6.2 shows annual revenue losses and avoided costs over time for level 3 standards, and Tables 6.7 through 6.9 show net revenue losses for all standards levels.

Cumulative net revenue losses for ovens range from \$0.3 to 2.6 billion. Cumulative changes in net revenues for cooktops range from a gain of \$0.4 to a loss of 0.7 billion. Cumulative net revenue losses for microwaves range from \$1.0 to 1.6 billion.

Figure 6.2 Revenue Reductions and Avoided Costs for Kitchen Ranges and Ovens

Table 6.7 Net Revenue Losses - Ovens (Million 1990 Dollars)

Year	Net Revenue Losses				
	Level 1	Level 2	Level 3	Level 4	Level 5
1996	4	6	14	19	35
1997	6	8	20	25	47
1998	7	10	25	32	59
1999	7	11	26	32	59
2000	8	12	30	37	68
2001	9	14	34	42	76
2002	10	15	38	46	83
2003	11	17	41	50	90
2004	12	18	44	54	96
2005	12	19	47	57	102
2006	13	20	50	60	107
2007	14	22	52	63	112
2008	15	23	54	66	117
2009	15	23	56	68	121
2010	15	23	57	69	123
2011	14	23	56	68	122
2012	13	22	55	67	119
2013	12	21	53	64	114
2014	12	20	50	61	108
2015	11	19	47	57	102
2016	10	17	44	53	95
2017	9	16	41	49	88
2018	8	14	37	45	81
2019	7	13	34	41	74
2020	6	11	31	37	67
2021	6	10	27	33	60
2022	5	9	24	29	54
2023	4	7	21	26	47
2024	3	6	18	22	40
2025	3	5	15	18	33
2026	2	4	12	14	27
2027	2	3	9	11	20
2028	1	2	6	7	13
2029	1	1	3	4	6
2030	0	0	0	0	0
Total	287	462	1174	1425	2563

Table 6.8 Net Revenue Losses - Cooktops (Million 1990 Dollars)

Year	Net Revenue Losses			
	Level 1	Level 2	Level 3	Level 4
1996	0	-2	-6	12
1997	0	-4	-8	14
1998	0	-7	-11	16
1999	0	-9	-13	14
2000	0	-12	-16	14
2001	0	-13	-18	16
2002	0	-13	-18	18
2003	0	-13	-18	20
2004	0	-13	-19	22
2005	0	-13	-19	24
2006	0	-13	-19	26
2007	0	-13	-19	28
2008	0	-13	-19	29
2009	0	-13	-19	31
2010	0	-13	-19	32
2011	0	-13	-19	31
2012	0	-13	-18	31
2013	0	-12	-17	30
2014	0	-11	-16	29
2015	0	-10	-15	28
2016	0	-9	-14	26
2017	0	-8	-13	24
2018	0	-8	-12	23
2019	0	-7	-11	21
2020	0	-7	-11	18
2021	0	-7	-10	16
2022	0	-7	-9	14
2023	0	-6	-8	12
2024	0	-5	-7	10
2025	0	-4	-6	9
2026	0	-4	-5	7
2027	0	-3	-4	5
2028	0	-2	-2	3
2029	0	-1	-1	2
2030	0	0	0	0
Total	-3	-302	-439	655

Table 6.9 Net Revenue Losses - Microwaves (Million 1990 Dollars)

Year	Net Revenue Losses				
	Level 1	Level 2	Level 3	Level 4	Level 5
1996	31	37	40	44	47
1997	40	45	50	55	58
1998	48	55	60	66	69
1999	47	54	59	64	68
2000	54	61	66	72	76
2001	59	67	72	79	83
2002	63	70	77	84	88
2003	66	73	79	86	91
2004	67	73	79	87	91
2005	66	72	78	85	89
2006	65	71	77	84	88
2007	63	70	75	82	86
2008	62	68	73	80	84
2009	60	66	72	78	82
2010	53	59	64	70	74
2011	44	50	55	61	64
2012	37	42	47	52	56
2013	29	34	39	44	47
2014	23	27	31	37	40
2015	17	21	25	30	33
2016	11	16	19	24	27
2017	7	11	14	19	21
2018	4	7	10	15	17
2019	1	5	8	12	14
2020	0	3	6	10	12
2021	0	3	5	8	10
2022	0	2	5	7	9
2023	0	2	4	7	8
2024	0	2	4	6	7
2025	0	2	3	5	6
2026	0	1	2	4	5
2027	0	1	2	3	3
2028	0	1	1	2	2
2029	0	0	1	1	1
2030	0	0	0	0	0
Total	1017	1171	1304	1463	1555

The figures in Tables 6.7 to 6.9 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.

Total residential rates would increase 0.1% and 0.1% (0.01¢/kWh and 0.01¢/kWh) in 2000 and

2005, respectively, if ovens are subject to level 4 standards, cooktops are subject to level 2 standards, microwaves are subject to level 3 standards, and regulators only change residential rates to compensate for any loss in revenue.

Tables 6.10 to 6.12 show the present value of net revenue losses at a 5% real utility discount rate for all standard 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 6.10 Present Value of Revenue Losses - Ovens (Million 1990 Dollars)

Regulatory Lag	Level 1	Level 2	Level 3	Level 4	Level 5
None	0	0	0	0	0
1996-2001	22	31	77	97	179
1996-2030	116	182	457	557	1004

Table 6.11 Present Value of Revenue Losses - Cooktops (Million 1990 Dollars)

Regulatory Lag	Level 1	Level 2	Level 3	Level 4
None	0	0	0	0
1996-2001	-1	-23	-36	47
1996-2030	-2	-122	-178	253

Table 6.12 Present Value of Revenue Losses Microwaves (Million 1990 Dollars)

Regulatory Lag	Level 1	Level 2	Level 3	Level 4	Level 5
None	0	0	0	0	0
1996-2001	148	169	185	202	213
1996-2030	501	569	626	694	734

For ovens, the present value of net lost revenues may range from \$0.02 to 0.2 billion for a five-year lag, and would be as large as \$1 billion if the regulators did not make adjustments. For cooktops, the present value of the change in net revenues may range from a gain of \$0.04 to a loss of \$0.05 billion for a five-year lag and would be as large as \$0.3 billion if the regulators did not make adjustments. For microwaves, the present value of net lost revenues may range from 0.15 to 0.2 billion for a five-year lag, and would be as large as \$0.7 billion if the regulators did not make adjustments. The present values over the period 1996 to 2030 also represent the rate increases or decreases needed over this period to compensate for lost revenues, assuming that regulators adjust immediately.

6.5 Sensitivity Analysis

Tables 6.13 through 6.15 show the peak-demand reductions for the sensitivity cases, Tables 6.16 through 6.18 show capacity savings. Tables 6.19 through 6.21 show the present value of net lost revenues for the same sensitivity cases. The assumptions for the sensitivity cases are the same as those for previous tables.

Table 6.13 Peak Demand Reductions (GW) Ovens (Sensitivity Cases 1, 2, 3, 4, 5, 6)

Year	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
1996	0.0	0.1	0.2	0.2	0.1	0.2
2000	0.2	0.4	0.4	0.4	0.2	0.3
2010	0.4	1.0	1.0	1.0	0.4	0.7
2020	0.5	1.2	1.2	1.1	0.2	0.6
2030	0.5	1.3	1.2	1.1	0.0	0.6

Table 6.14 Peak Demand Reductions (GW) Cooktops (Sensitivity Cases 1, 2, 3, 4, 5, 6)

Year	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
1996	0.0	0.0	0.0	0.0	0.0	0.0
2000	0.0	0.0	0.0	0.0	0.0	0.0
2010	0.0	0.2	0.1	0.1	-0.1	0.0
2020	0.0	0.3	0.2	0.1	-0.1	0.0
2030	0.1	0.3	0.2	0.2	-0.1	0.1

Table 6.15 Peak Demand Reductions (GW) Microwaves (Sensitivity Cases 1, 2, 3, 4, 5, 6)

Year	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
1996	0.0	0.3	0.3	0.3	0.0	0.0
2000	0.1	0.6	0.6	0.6	0.1	0.1
2010	0.1	0.9	0.9	0.4	0.0	0.1
2020	0.1	0.9	0.5	0.1	0.0	0.1
2030	0.1	1.0	0.2	0.1	0.0	0.1

Table 6.16 Capacity Savings (GW) Ovens (Sensitivity Cases 1, 2, 3, 4, 5, 6)

Year	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
1996	0.0	0.1	0.1	0.1	0.1	0.1
2000	0.2	0.5	0.5	0.5	0.3	0.4
2010	0.5	1.2	1.3	1.2	0.4	0.8
2020	0.6	1.4	1.4	1.3	0.2	0.8
2030	0.6	1.6	1.4	1.4	0.0	0.7

Table 6.17 Capacity Savings (GW) Cooktops (Sensitivity Cases 1, 2, 3, 4, 5, 6)

Year	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
1996	0.0	0.0	0.0	0.0	0.0	0.0
2000	0.0	0.1	0.1	0.1	-0.1	0.0
2010	0.0	0.2	0.2	0.1	-0.1	0.0
2020	0.0	0.3	0.2	0.1	-0.1	0.1
2030	0.2	0.4	0.2	0.2	-0.1	0.1

Table 6.18 Capacity Savings (GW) Microwaves (Sensitivity Cases 1, 2, 3, 4, 5, 6)

Year	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
1996	0.0	0.2	0.2	0.2	0.0	0.0
2000	0.1	0.7	0.7	0.7	0.1	0.1
2010	0.1	1.0	1.1	0.5	0.0	0.1
2020	0.2	1.1	0.6	0.2	0.0	0.2
2030	0.2	1.2	0.2	0.2	0.0	0.2

**Table 6.19 Present Value of Revenue Losses Ovens (Sensitivity Cases 1, 2, 3, 4, 5, 6)
Million 1990 Dollars)**

Regulatory Lag	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
None	0	0	0	0	0	0
1996-2001	55	131	130	135	81	120
1996-2030	305	726	722	711	280	533

Table 6.20 Present Value of Revenue Losses Cooktops (Sensitivity Cases 1, 2, 3, 4, 5, 6)
Million 1990 Dollars)

Regulatory Lag	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
None	0	0	0	0	0	0
1996-2001	-6	20	15	13	-11	-2
1996-2030	-21	120	90	75	-66	-1

Table 6.21 Present Value of Revenue Losses Microwaves (Sensitivity Cases 1, 2, 3, 4, 5, 6)
Million 1990 Dollars)

Regulatory Lag	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
None	0	0	0	0	0	0
1996-2001	34	196	190	199	25	27
1996-2030	121	767	717	560	36	115

CHAPTER 7. ENVIRONMENTAL EFFECTS

7.1 INTRODUCTION

The environmental effects from a range of new candidate energy-conservation standards for cooking appliances are presented here. The results are presented for each potential standard 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 it is compared to what is expected to happen if no new standards for cooking appliances were finalized, i.e., the "no action" alternative.

The main environmental concern addressed is 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 standards 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, or 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 is considered an environmental hazard because it contributes to the "greenhouse effect" by trapping heat energy from the earth that is emitted 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 A of this Technical Support Document.

7.2 RESULTS

The following tabular results indicate what changes can be brought about in the amounts of emitted CO_2 , SO_2 , and NO_x by imposing efficiency standards for each of the three types of cooking appliances. A table is presented for each of the appliances' trial standards levels. Each appliance has been analyzed separately in order to determine the emission changes resulting from each of their prospective trial standards levels. Each table details 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 trial standards level. Each table includes the following information for a specific year between 1996 and 2030: the amount of emission abated from power plant generation, the amount abated from in-home 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 1996 and 2030).

Decreases in the amounts of CO₂, SO₂, and NO_x are presented for cooktops, conventional ovens, and microwave ovens. Trial standards levels 1 through 5 for cooktops are summarized in Tables 7.1 through 7.5, trial standards levels 1 through 5 for conventional ovens are summarized in Tables 7.6 through 7.10, and trial standards 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 0.09 million tons between 1996 and 2030 in the level 5 scenario. In the year 1996, decreases in SO₂ will represent about 0.01% of the SO₂ emissions estimated to come from power plants in that year. In the year 2030, decreases in SO₂ emissions will represent about 0.04% of the SO₂ emissions estimated to come from power plants in that year. Because of provisions in the Clean Air Act Amendments (Pub. L. 101-549, November 15, 1990), the possible reductions of SO₂ that are caused by standards can be earned as credits by the utility realizing the reductions. To the extent SO₂ credits are used for future emissions, the net effect on SO₂ emissions from standards would be only a postponement of those SO₂ emissions.

Level 5 design changes to cooktops would result in an estimated decrease in NO_x emissions of 0.21 million tons between 1996 and 2030. NO_x decreases would represent 0.02% and 0.11% of the NO_x emissions estimated to come from power plants in the years 1996 and 2030, respectively.

Conventional Ovens

Sulfur dioxide emissions would be decreased by a cumulative total of up to 0.40 million tons between 1996 and 2030 in the level 5 scenario. In the year 1996, decreases in SO₂ will represent about 0.04% of the SO₂ emissions estimated to come from power plants in that year. In the year 2030, decreases in SO₂ emissions will represent about 0.15% of the SO₂ emissions estimated to come from power plants in that year. As discussed above, the possible reductions of SO₂ emissions caused by standards can be earned as credits. To the extent credits are used for future emissions, the standards' net effect on those SO₂ emissions would be only a postponement.

Level 5 design changes to conventional ovens would result in an estimated decrease in NO_x emissions of 0.45 million tons between 1996 and 2030. NO_x decreases would represent 0.05% and 0.19% of the NO_x emissions estimated to come from power plants in the years 1996 and 2030, respectively.

Microwave Ovens

Sulfur dioxide emissions would be decreased by a cumulative total of up to 0.19 million tons between 1996 and 2030 in the level 5 scenario. In the year 1996, decreases in SO₂ will represent about 0.05% of the SO₂ emissions estimated to come from power plants in that year. In the year 2030, decreases in SO₂ emissions will represent about 0.02% of the SO₂ emissions estimated to come from power plants in that year. As discussed above, the possible reductions of SO₂ emissions caused by standards can be earned as credits. To the extent credits are used for future emissions, the standards' net effect on those SO₂ emissions would be only a postponement.

Level 5 design changes to microwave ovens would result in an estimated decrease in NO_x emissions of 0.16 million tons between 1996 and 2030. NO_x decreases would represent 0.05% and 0.02% of the NO_x emissions estimated to come from power plants in the years 1996 and 2030, respectively.

7.2.2 Carbon Dioxide Emissions

Cooktops

The cumulative reduction in CO₂ emissions from level 5 design changes is 172 million tons of CO₂. For the year 1996, the estimated CO₂ reduction is 1028 thousand tons of CO₂ or about 0.04% of estimated U.S. total CO₂ emissions in 1996. For the year 2030, the estimated CO₂ reduction is 6139 thousand tons of CO₂, or about 0.13% of estimated U.S. total CO₂ emissions in 2030.

Conventional Ovens

The cumulative reduction in CO₂ emissions from level 5 design changes is 280 million tons of CO₂. For the year 1996, the estimated CO₂ reduction is 1442 thousand tons of CO₂ or about 0.06% of estimated U.S. total CO₂ emissions in 1996. For the year 2030, the estimated CO₂ reduction is 9897 thousand tons of CO₂, or about 0.21% of estimated U.S. total CO₂ emissions in 2030.

Microwave Ovens

The cumulative reduction in CO₂ emissions from level 5 design changes is 71 million tons of CO₂. For the year 1996, the estimated CO₂ reduction is 1085 thousand tons of CO₂, or about 0.05% of estimated U.S. total CO₂ emissions in 1996. For the year 2030, the estimated CO₂ reduction is 1076 thousand tons of CO₂, or about 0.02% of estimated U.S. total CO₂ emissions in 2030.

Table 7.1
Reduction of Pollutants for Cooktops - Level One

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	0	55	55	0.00%
2000	0	55	55	0.00%
2005	0	55	55	0.00%
2010	0	55	55	0.00%
2015	0	0	0	0.00%
2020	0	0	0	0.00%
2025	0	0	0	0.00%
2030	0	0	0	0.00%

Cumulative CO2 reduction, 1996-2030 = 1 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	0	0	0	0.00%
2000	0	0	0	0.00%
2005	0	0	0	0.00%
2010	0	0	0	0.00%
2015	0	0	0	0.00%
2020	0	0	0	0.00%
2025	0	0	0	0.00%
2030	0	0	0	0.00%

Cumulative SO2 reduction, 1996-2030 = 265 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. NOx Power Plant Emissions
1996	0	53	53	0.00%
2000	0	53	53	0.00%
2005	0	53	53	0.00%
2010	0	53	53	0.00%
2015	0	0	0	0.00%
2020	0	0	0	0.00%
2025	0	0	0	0.00%
2030	0	0	0	0.00%

Cumulative NOx reduction, 1996-2030 = 997 tons

Table 7.2
Reduction of Pollutants for Cooktops - Level Two

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	86	715	801	0.04%
2000	168	1,760	1,928	0.08%
2005	338	3,080	3,418	0.12%
2010	510	4,290	4,800	0.15%
2015	508	4,675	5,183	0.14%
2020	422	4,675	5,097	0.13%
2025	417	4,675	5,092	0.12%
2030	580	4,565	5,145	0.11%

Cumulative CO2 reduction, 1996-2030 = 144 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	483	0	483	0.00%
2000	602	0	602	0.01%
2005	1,027	0	1,027	0.01%
2010	1,331	0	1,331	0.02%
2015	1,067	0	1,067	0.01%
2020	713	0	713	0.01%
2025	547	0	547	0.01%
2030	579	0	579	0.01%

Cumulative SO2 reduction, 1996-2030 = 29,529 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	%U.S. NOx Power Plant Emissions
1996	303	682	986	0.01%
2000	448	1,680	2,128	0.03%
2005	826	2,940	3,766	0.05%
2010	1,156	4,095	5,251	0.07%
2015	990	4,463	5,452	0.08%
2020	713	4,463	5,175	0.08%
2025	600	4,463	5,062	0.08%
2030	712	4,358	5,069	0.09%

Cumulative NOx reduction, 1996-2030 = 151,231 tons

Table 7.3
Reduction of Pollutants for Cooktops - Level Three

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	0	880	880	0.04%
2000	84	2,035	2,119	0.08%
2005	253	3,410	3,663	0.13%
2010	255	4,675	4,930	0.15%
2015	338	5,005	5,343	0.15%
2020	253	5,005	5,258	0.13%
2025	250	5,005	5,255	0.12%
2030	331	4,895	5,226	0.11%

Cumulative CO2 reduction, 1996-2030 = 150 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	0	0	0	0.00%
2000	301	0	301	0.00%
2005	770	0	770	0.01%
2010	665	0	665	0.01%
2015	712	0	712	0.01%
2020	428	0	428	0.01%
2025	328	0	328	0.01%
2030	331	0	331	0.01%

Cumulative SO2 reduction, 1996-2030 = 17,264 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	%U.S. NOx Power Plant Emissions
1996	0	840	840	0.01%
2000	224	1,943	2,167	0.03%
2005	620	3,255	3,875	0.06%
2010	578	4,463	5,041	0.07%
2015	660	4,778	5,437	0.08%
2020	428	4,778	5,205	0.08%
2025	360	4,778	5,137	0.08%
2030	407	4,673	5,079	0.09%

Cumulative NOx reduction, 1996-2030 = 150,971 tons

Table 7.4
Reduction of Pollutants for Cooktops - Level Four

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	430	715	1,145	0.05%
2000	922	1,705	2,627	0.10%
2005	1,690	2,860	4,550	0.16%
2010	2,380	3,905	6,285	0.20%
2015	2,708	4,180	6,888	0.19%
2020	2,698	4,180	6,878	0.17%
2025	2,671	4,125	6,796	0.16%
2030	2,898	4,070	6,968	0.15%

Cumulative CO2 reduction, 1996-2030 = 193 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	2,416	0	2,416	0.02%
2000	3,312	0	3,312	0.04%
2005	5,135	0	5,135	0.06%
2010	6,210	0	6,210	0.07%
2015	5,692	0	5,692	0.07%
2020	4,561	0	4,561	0.07%
2025	3,503	0	3,503	0.06%
2030	2,895	0	2,895	0.06%

Cumulative SO2 reduction, 1996-2030 = 156,128 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	%U.S. NOx Power Plant Emissions
1996	1,517	682	2,199	0.03%
2000	2,466	1,628	4,093	0.06%
2005	4,132	2,730	6,862	0.10%
2010	5,397	3,728	9,124	0.12%
2015	5,278	3,990	9,268	0.13%
2020	4,561	3,990	8,551	0.13%
2025	3,838	3,938	7,776	0.12%
2030	3,558	3,885	7,443	0.13%

Cumulative NOx reduction, 1996-2030 = 254,836 tons

Table 7.5
Reduction of Pollutants for Cooktops - Level Five

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	258	770	1,028	0.04%
2000	503	1,815	2,318	0.09%
2005	1,014	3,080	4,094	0.14%
2010	1,445	4,235	5,680	0.18%
2015	1,608	4,510	6,118	0.17%
2020	1,602	4,510	6,112	0.15%
2025	1,586	4,510	6,096	0.14%
2030	1,739	4,400	6,139	0.13%

Cumulative CO2 reduction, 1996-2030 = 172 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	1,450	0	1,450	0.01%
2000	1,807	0	1,807	0.02%
2005	3,081	0	3,081	0.04%
2010	3,770	0	3,770	0.04%
2015	3,380	0	3,380	0.04%
2020	2,708	0	2,708	0.04%
2025	2,080	0	2,080	0.04%
2030	1,737	0	1,737	0.04%

Cumulative SO2 reduction, 1996-2030 = 92,421 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	%U.S. NOx Power Plant Emissions
1996	910	735	1,645	0.02%
2000	1,345	1,733	3,077	0.05%
2005	2,479	2,940	5,419	0.08%
2010	3,277	4,043	7,319	0.10%
2015	3,134	4,305	7,439	0.11%
2020	2,708	4,305	7,013	0.10%
2025	2,279	4,305	6,584	0.10%
2030	2,135	4,200	6,335	0.11%

Cumulative NOx reduction, 1996-2030 = 206,040 tons

Table 7.6
Reduction of Pollutants for Ovens - Level One

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	86	110	196	0.01%
2000	335	275	610	0.02%
2005	676	550	1,226	0.04%
2010	850	770	1,620	0.05%
2015	846	880	1,726	0.05%
2020	843	825	1,668	0.04%
2025	668	770	1,438	0.03%
2030	745	715	1,460	0.03%

Cumulative CO2 reduction, 1996-2030 = 46 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	483	0	483	0.00%
2000	1,204	0	1,204	0.01%
2005	2,054	0	2,054	0.02%
2010	2,218	0	2,218	0.03%
2015	1,779	0	1,779	0.02%
2020	1,425	0	1,425	0.02%
2025	876	0	876	0.02%
2030	744	0	744	0.02%

Cumulative SO2 reduction, 1996-2030 = 51,111 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	%U.S. NOx Power Plant Emissions
1996	303	105	408	0.01%
2000	897	262	1,159	0.02%
2005	1,653	525	2,178	0.03%
2010	1,927	735	2,662	0.04%
2015	1,649	840	2,489	0.04%
2020	1,425	788	2,213	0.03%
2025	960	735	1,695	0.03%
2030	915	683	1,598	0.03%

Cumulative NOx reduction, 1996-2030 = 67,149 tons

Table 7.7
Reduction of Pollutants for Ovens - Level Two

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	172	275	447	0.02%
2000	587	660	1,247	0.05%
2005	1,098	1,265	2,363	0.08%
2010	1,530	1,705	3,235	0.10%
2015	1,608	1,925	3,533	0.10%
2020	1,518	1,815	3,333	0.08%
2025	1,336	1,705	3,041	0.07%
2030	1,407	1,485	2,892	0.06%

Cumulative CO2 reduction, 1996-2030 = 93 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	966	0	966	0.01%
2000	2,108	0	2,108	0.02%
2005	3,338	0	3,338	0.04%
2010	3,992	0	3,992	0.05%
2015	3,380	0	3,380	0.04%
2020	2,565	0	2,565	0.04%
2025	1,752	0	1,752	0.03%
2030	1,406	0	1,406	0.03%

Cumulative SO2 reduction, 1996-2030 = 91,860 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	%U.S. NOx Power Plant Emissions
1996	607	263	869	0.01%
2000	1,569	630	2,199	0.03%
2005	2,686	1,208	3,893	0.06%
2010	3,469	1,628	5,097	0.07%
2015	3,134	1,838	4,971	0.07%
2020	2,565	1,733	4,298	0.06%
2025	1,919	1,628	3,547	0.06%
2030	1,728	1,418	3,146	0.05%

Cumulative NOx reduction, 1996-2030 = 130,408 tons

Table 7.8
Reduction of Pollutants for Ovens - Level Three

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	430	385	815	0.04%
2000	1,174	935	2,109	0.08%
2005	2,281	1,705	3,986	0.14%
2010	3,230	2,365	5,595	0.17%
2015	3,470	2,585	6,055	0.17%
2020	3,457	2,475	5,932	0.15%
2025	3,339	2,365	5,704	0.13%
2030	3,394	2,200	5,594	0.12%

Cumulative CO2 reduction, 1996-2030 = 165 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	2,416	0	2,416	0.02%
2000	4,215	0	4,215	0.05%
2005	6,933	0	6,933	0.08%
2010	8,428	0	8,428	0.10%
2015	7,293	0	7,293	0.10%
2020	5,843	0	5,843	0.09%
2025	4,379	0	4,379	0.08%
2030	3,391	0	3,391	0.07%

Cumulative SO2 reduction, 1996-2030 = 201,949 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	%U.S. NOx Power Plant Emissions
1996	1,517	368	1,884	0.02%
2000	3,138	893	4,031	0.06%
2005	5,578	1,628	7,205	0.10%
2010	7,324	2,258	9,582	0.13%
2015	6,762	2,468	9,229	0.13%
2020	5,843	2,363	8,206	0.12%
2025	4,798	2,258	7,056	0.11%
2030	4,168	2,100	6,268	0.11%

Cumulative NOx reduction, 1996-2030 = 249,364 tons

Table 7.9
Reduction of Pollutants for Ovens - Level Four

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	516	440	956	0.04%
2000	1,425	990	2,415	0.10%
2005	2,704	1,815	4,519	0.16%
2010	3,825	2,475	6,300	0.20%
2015	4,147	2,750	6,897	0.19%
2020	4,048	2,640	6,688	0.17%
2025	4,007	2,530	6,537	0.15%
2030	4,057	2,365	6,422	0.13%

Cumulative CO2 reduction, 1996-2030 = 187 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	2,899	0	2,899	0.02%
2000	5,119	0	5,119	0.06%
2005	8,216	0	8,216	0.09%
2010	9,980	0	9,980	0.12%
2015	8,716	0	8,716	0.11%
2020	6,841	0	6,841	0.10%
2025	5,255	0	5,255	0.09%
2030	4,053	0	4,053	0.08%

Cumulative SO2 reduction, 1996-2030 = 238,528 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	%U.S. NOx Power Plant Emissions
1996	1,820	420	2,240	0.03%
2000	3,811	945	4,756	0.07%
2005	6,611	1,733	8,343	0.12%
2010	8,673	2,363	11,036	0.15%
2015	8,081	2,625	10,706	0.15%
2020	6,841	2,520	9,361	0.14%
2025	5,758	2,415	8,173	0.13%
2030	4,982	2,258	7,239	0.12%

Cumulative NOx reduction, 1996-2030 = 287,223 tons

Table 7.10
Reduction of Pollutants for Ovens - Level Five

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	947	495	1,442	0.06%
2000	2,432	1,210	3,642	0.15%
2005	4,478	2,090	6,568	0.23%
2010	6,375	2,915	9,290	0.29%
2015	6,939	3,190	10,129	0.28%
2020	6,999	3,135	10,134	0.26%
2025	6,928	3,025	9,953	0.23%
2030	7,037	2,860	9,897	0.21%

Cumulative CO2 reduction, 1996-2030 = 280 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	5,316	0	5,316	0.04%
2000	8,732	0	8,732	0.10%
2005	13,609	0	13,609	0.16%
2010	16,633	0	16,633	0.20%
2015	14,586	0	14,586	0.19%
2020	11,829	0	11,829	0.18%
2025	9,087	0	9,087	0.16%
2030	7,031	0	7,031	0.15%

Cumulative SO2 reduction, 1996-2030 = 404,878 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	%U.S. NOx Power Plant Emissions
1996	3,337	473	3,809	0.05%
2000	6,500	1,155	7,655	0.11%
2005	10,949	1,995	12,944	0.18%
2010	14,455	2,783	17,238	0.24%
2015	13,524	3,045	16,569	0.24%
2020	11,829	2,993	14,822	0.22%
2025	9,956	2,888	12,843	0.20%
2030	8,642	2,730	11,372	0.19%

Cumulative NOx reduction, 1996-2030 = 451,360 tons

Table 7.11
Reduction of Pollutants for Microwave Ovens - Level One

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	723	0	723	0.03%
2000	1,643	0	1,643	0.07%
2005	2,492	0	2,492	0.09%
2010	2,380	0	2,380	0.07%
2015	982	0	982	0.03%
2020	17	0	17	0.00%
2025	-8	0	-8	0.00%
2030	-8	0	-8	0.00%

Cumulative CO2 reduction, 1996-2030 = 39 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	4,059	0	4,059	0.03%
2000	5,901	0	5,901	0.07%
2005	7,575	0	7,575	0.09%
2010	6,210	0	6,210	0.07%
2015	2,063	0	2,063	0.03%
2020	29	0	29	0.00%
2025	-11	0	-11	0.00%
2030	-8	0	-8	0.00%

Cumulative SO2 reduction, 1996-2030 = 118,044 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	%U.S. NOx Power Plant Emissions
1996	2,548	0	2,548	0.03%
2000	4,393	0	4,393	0.07%
2005	6,094	0	6,094	0.09%
2010	5,397	0	5,397	0.07%
2015	1,913	0	1,913	0.03%
2020	29	0	29	0.00%
2025	-12	0	-12	0.00%
2030	-10	0	-10	0.00%

Cumulative NOx reduction, 1996-2030 = 94,479 tons

Table 7.12
Reduction of Pollutants for Microwave Ovens - Level Two

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	844	0	844	0.04%
2000	1,845	0	1,845	0.07%
2005	2,737	0	2,737	0.10%
2010	2,643	0	2,643	0.08%
2015	1,252	0	1,252	0.03%
2020	295	0	295	0.01%
2025	284	0	284	0.01%
2030	290	0	290	0.01%

Cumulative CO2 reduction, 1996-2030 = 48 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	4,736	0	4,736	0.04%
2000	6,624	0	6,624	0.07%
2005	8,319	0	8,319	0.10%
2010	6,897	0	6,897	0.08%
2015	2,633	0	2,633	0.03%
2020	499	0	499	0.01%
2025	372	0	372	0.01%
2030	289	0	289	0.01%

Cumulative SO2 reduction, 1996-2030 = 138,308 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. NOx Power Plant Emissions
1996	2,973	0	2,973	0.04%
2000	4,931	0	4,931	0.07%
2005	6,694	0	6,694	0.10%
2010	5,994	0	5,994	0.08%
2015	2,441	0	2,441	0.03%
2020	499	0	499	0.01%
2025	408	0	408	0.01%
2030	356	0	356	0.01%

Cumulative NOx reduction, 1996-2030 = 112,216 tons

Table 7.13
Reduction of Pollutants for Microwave Ovens - Level Three

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	938	0	938	0.04%
2000	2,012	0	2,012	0.08%
2005	2,957	0	2,957	0.10%
2010	2,873	0	2,873	0.09%
2015	1,498	0	1,498	0.04%
2020	548	0	548	0.01%
2025	543	0	543	0.01%
2030	563	0	563	0.01%

Cumulative CO2 reduction, 1996-2030 = 56 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	5,267	0	5,267	0.04%
2000	7,226	0	7,226	0.08%
2005	8,987	0	8,987	0.10%
2010	7,496	0	7,496	0.09%
2015	3,149	0	3,149	0.04%
2020	926	0	926	0.01%
2025	712	0	712	0.01%
2030	562	0	562	0.01%

Cumulative SO2 reduction, 1996-2030 = 156,181 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	%U.S. NOx Power Plant Emissions
1996	3,306	0	3,306	0.04%
2000	5,380	0	5,380	0.08%
2005	7,231	0	7,231	0.10%
2010	6,515	0	6,515	0.09%
2015	2,919	0	2,919	0.04%
2020	926	0	926	0.01%
2025	780	0	780	0.01%
2030	691	0	691	0.01%

Cumulative NOx reduction, 1996-2030 = 127,936 tons

Table 7.14
Reduction of Pollutants for Microwave Ovens - Level Four

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	1,024	0	1,024	0.04%
2000	2,205	0	2,205	0.09%
2005	3,236	0	3,236	0.11%
2010	3,170	0	3,170	0.10%
2015	1,803	0	1,803	0.05%
2020	869	0	869	0.02%
2025	868	0	868	0.02%
2030	894	0	894	0.02%

Cumulative CO2 reduction, 1996-2030 = 65 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	5,751	0	5,751	0.04%
2000	7,919	0	7,919	0.09%
2005	9,834	0	9,834	0.11%
2010	8,272	0	8,272	0.10%
2015	3,789	0	3,789	0.05%
2020	1,468	0	1,468	0.02%
2025	1,139	0	1,139	0.02%
2030	893	0	893	0.02%

Cumulative SO2 reduction, 1996-2030 = 177,609 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	%U.S. NOx Power Plant Emissions
1996	3,610	0	3,610	0.04%
2000	5,895	0	5,895	0.09%
2005	7,912	0	7,912	0.11%
2010	7,189	0	7,189	0.10%
2015	3,513	0	3,513	0.05%
2020	1,468	0	1,468	0.02%
2025	1,247	0	1,247	0.02%
2030	1,098	0	1,098	0.02%

Cumulative NOx reduction, 1996-2030 = 146,928 tons

Table 7.15
Reduction of Pollutants for Microwave Ovens - Level Five

CO2 Reduction (in Thousand Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. CO2 Power Plant Emissions
1996	1,085	0	1,085	0.05%
2000	2,323	0	2,323	0.09%
2005	3,388	0	3,388	0.12%
2010	3,332	0	3,332	0.10%
2015	1,972	0	1,972	0.05%
2020	1,046	0	1,046	0.03%
2025	1,052	0	1,052	0.02%
2030	1,076	0	1,076	0.02%

Cumulative CO2 reduction, 1996-2030 = 71 million tons of CO2

SO2 Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	% U.S. SO2 Power Plant Emissions
1996	6,089	0	6,089	0.05%
2000	8,340	0	8,340	0.09%
2005	10,296	0	10,296	0.12%
2010	8,694	0	8,694	0.10%
2015	4,145	0	4,145	0.05%
2020	1,767	0	1,767	0.03%
2025	1,379	0	1,379	0.02%
2030	1,075	0	1,075	0.02%

Cumulative SO2 reduction, 1996-2030 = 189,945 tons

NOx Reduction (in Tons)

Year	Abated from Power Plant Generation	Abated from In-Home Generation	Net Change	%U.S. NOx Power Plant Emissions
1996	3,822	0	3,822	0.05%
2000	6,209	0	6,209	0.09%
2005	8,284	0	8,284	0.12%
2010	7,555	0	7,555	0.10%
2015	3,843	0	3,843	0.05%
2020	1,767	0	1,767	0.03%
2025	1,511	0	1,511	0.02%
2030	1,322	0	1,322	0.02%

Cumulative NOx reduction, 1996-2030 = 157,793 tons

APPENDIX A. ENGINEERING ANALYSIS – SUPPORTING DOCUMENTATION

A.1 ADJUSTED ANNUAL USEFUL COOKING-ENERGY OUTPUT

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. 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. The estimated average cooking-energy consumption using the DOE test procedure with both the adjusted and unadjusted annual useful cooking-energy output are included for comparison. The estimates from the DOE test procedure shown in the figures are the average of standard and self-cleaning ovens weighted by sales. The gas cooking-energy estimate is also sales-weighted by units with and without power cords. The data used in these figures are listed in Table A.1 and Table A.2. The sources of the data are described in the notes following this section.

Figure A.1 Annual Gas Cooking-Energy Consumption

Figure A.2 Annual Electric Cooking-Energy Consumption

Table A.1 Annual Electric Cooking-Energy Consumption

Source	Year	Cooktop	Oven	Range	Units	Type
DOE		359.5	426.9	786.4	kWH	calculated
Adjusted		271.1	338.0	609.1	kWH	calculated
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

Table A.2 Annual Gas Cooking-Energy Consumption

Source	Year	Cooktop	Oven	Range	Units	Type	Pilot
DOE		29.2	32.9	62.2	therms	calculated	yes & no
Adjusted		23.8	27.2	51.1	therms	calculated	both
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

An average annual useful cooking-energy output was calculated from utility studies (shown above) of annual cooking-energy consumption, DOE assumptions, baseline efficiencies and 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 studies⁷ done in California. Because of the building codes 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.

⁷These are the studies listed as SCE '88, BSG/Xenergy '88, CEC '87, and SoCal '84 for gas in Table A.1.

$$\begin{aligned}
UEC_{\text{gas cooking}} &= 41.8 \text{ therms} \\
&= MS_{\text{g}_{\text{sc}}} * UEC_{\text{gas oven sc}} \\
&\quad + (1 - MS_{\text{g}_{\text{sc}}}) * UEC_{\text{gas oven}} \\
&\quad + UEC_{\text{gas cooktop}}
\end{aligned} \tag{A.1}$$

where:

- $MS_{\text{g}_{\text{sc}}}$ = the market share of gas ovens that are self-cleaning, 23.74% (60),
- $UEC_{\text{gas oven sc}}$ = unit energy consumption for self-cleaning gas ovens,
- $UEC_{\text{gas oven}}$ = unit energy consumption for standard gas ovens, and
- $UEC_{\text{gas cooktop}}$ = 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 were

$$UEC_{\text{gas oven sc}} = R_{\text{g}_{\text{sc std}}} * UEC_{\text{gas oven}} + E_{\text{gs}} * S_{\text{g}} \tag{A.2}$$

and

$$UEC_{\text{gas cooktop}} = R_{\text{g}_{\text{ct std}}} * UEC_{\text{gas oven}} \tag{A.3}$$

where:

- $R_{\text{g}_{\text{sc std}}}$ = the ratio of self-cleaning gas oven cooking energy to standard gas oven cooking energy,
- $R_{\text{g}_{\text{ct std}}}$ = 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, and
- S_{g} = number of self-clean cycles per year for gas ovens, 7 from DOE (61).

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 1.3.2, 1.4.2, and 1.5.2). This assumes that the ratio of annual useful cooking-energy output for cooktops compared to ovens has not changed significantly.

$$R_{g_{sc} \text{ std}} = \frac{(Oo_{DOE} / EFF_{go_{sc}})}{(Oo_{DOE} / EFF_{go_{std}})} = 0.827 \quad (A.4)$$

$$R_{g_{ct} \text{ std}} = \frac{(Oct_{DOE} / EFF_{g_{ct}})}{(Oo_{DOE} / EFF_{go_{std}})} = 0.872 \quad (A.5)$$

where:

Oo_{DOE}	=	the annual useful cooking-energy output for ovens according to the old DOE test procedure (62), 1.607 therms,
Oct_{DOE}	=	the annual useful cooking-energy output for cooktops according to the old DOE test procedure (63), 9.475 therms,
$EFF_{go_{sc}}$	=	the cooking efficiency of the baseline self-cleaning gas oven, from the cost/efficiency table, 7.13%,
$EFF_{go_{std}}$	=	the cooking efficiency of the baseline standard gas oven, from the cost/efficiency table, 5.9%, and
$EFF_{g_{ct}}$	=	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:

$$\begin{aligned}
 UEC_{\text{gas cooking}} &= MS_{g_{sc}} * (R_{g_{sc} \text{ std}} * UEC_{\text{gas oven}} + E_{gs} * S_g) \\
 &+ (1 - MS_{g_{sc}}) * UEC_{\text{gas oven}} \\
 &+ R_{g_{ct} \text{ std}} * UEC_{\text{gas oven}}
 \end{aligned} \quad (A.6)$$

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

$$UEC_{\text{gas oven}} = \frac{UEC_{\text{gas cooking}} - E_{\text{gs}} * S_{\text{g}}}{(MS_{\text{g sc}} * (R_{\text{g sc std}} - 1) + R_{\text{g ct std}} + 1)} = 21.1 \text{ therms} \quad (\text{A.7})$$

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 oven. Using the baseline efficiency from the cost/efficiency table and solving for the annual useful oven cooking-energy output gives 1.24 therms.

$$O_{\text{o adj}} = UEC_{\text{gas oven}} * EFF_{\text{go std}} = 1.24 \text{ therms} \quad (\text{A.8})$$

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.

$$O_{\text{ct adj}} = R_{\text{g ct std}} * UEC_{\text{gas oven}} * EFF_{\text{g ct}} = 7.32 \text{ therms} \quad (\text{A.9})$$

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 studies⁸ 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.

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

⁸These 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% (64)
- $UEC_{elec oven sc}$ = unit energy consumption for self-cleaning electric ovens,
- = unit energy consumption for standard electric ovens, and
- = unit energy consumption for electric 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 were:

$$UEC_{elec oven sc} = Re_{sc std} * UEC_{elec oven} + Ees * Se \quad (A.11)$$

and

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

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, and
- Se = number of self-clean cycles per year for electric ovens, 11 from DOE (65).

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 1.3.2, 1.4.2, and 1.5.2). This assumes that the ratio of annual useful cooking-energy output for cooktops compared to ovens has not changed significantly.

$$Re_{sc \text{ std}} = \frac{(Oo_{DOE} / EFF_{eO_{SC}})}{(Oo_{DOE} / EFF_{eO_{std}})} = .871 \quad (A.13)$$

$$Re_{ct \text{ std}} = \frac{(Oct_{DOE} / EFF_{e_{ct}})}{(Oo_{DOE} / EFF_{eO_{std}})} = .924 \quad (A.14)$$

where:

Oo_{DOE}	=	the annual useful cooking energy output for ovens according to the old DOE test procedure 47.1 kWh, (66),
Oct_{DOE}	=	the annual useful cooking energy output for cooktops according to the old DOE test procedure 277.7 kWh, (67),
$EFF_{eO_{SC}}$	=	the cooking efficiency of the baseline self-cleaning electric oven, from the cost/efficiency table, 13.9%,
$EFF_{eO_{std}}$	=	the cooking efficiency of the baseline standard electric oven, from the cost/efficiency table, 12.1%, and
$EFF_{e_{ct}}$	=	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:

$$\begin{aligned} UEC_{elec \text{ cooking}} &= MSe_{sc} * (Re_{sc \text{ std}} * UEC_{elec \text{ oven}} + Ees * Se) \\ &+ (1 - MSe_{sc}) * UEC_{elec \text{ oven}} \\ &+ Re_{ct \text{ std}} * UEC_{elec \text{ oven}} \end{aligned} \quad (A.15)$$

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

$$UEC_{elec \text{ oven}} = \frac{UEC_{elec \text{ cooking}} - Ees * Se}{(MSe_{sc} * (Re_{sc \text{ std}} - 1) + Re_{ct \text{ std}} + 1)} = 293.4 \text{ kWh} \quad (A.16)$$

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 gives 35.5 kWh.

$$Oo_{adj} = UEC_{elec\ oven} * EFFEo_{std} = 35.5\ kWh \quad (A.17)$$

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 of 209.4 kWh.

$$Oct_{adj} = Re_{ct\ std} * UEC_{elec\ oven} * EFFE_{ct} = 209.4\ kWh \quad (A.18)$$

The annual useful cooktop and oven cooking-energy outputs were all converted to kBtus 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
Cooktop	947.5	732.5	714.3

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 Electric 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 Electric 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 are 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, BA, Uhlaner, RT and Cason, TN "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, FD and Parris, KM, "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 are 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 are from Lawrence, AG and Ignelzi, PC "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, FD and Parris, KM, "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 UEC: Single-Family Dwellings," p 3-20.

BG&E (88)

Listed in Sebold, FD and Parris, KM, "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 UEC: 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, FD and Parris, KM, "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 UEC: Single-Family Dwellings," p 3-20.

TNP (88)

Listed in Sebold, FD and Parris, KM, "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 UEC: 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, FD and Parris, KM, "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, FD and Parris, KM, "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 UEC: All Dwellings," p 3-19.

JCP&L (87)

Listed in Sebold, FD and Parris, KM, "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 UEC: All Dwellings," p 3-19.

MetEd (87)

Listed in Sebold, FD and Parris, KM, "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 UEC: All Dwellings," p 3-19.

PG&E (87)

Listed in Sebold, FD and Parris, KM, "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 UEC: All Dwellings," p 3-19.

VEPCO (87)

Listed in Sebold, FD and Parris, KM, "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 UEC: Single-Family Dwellings," p 3-20.

ACEEE

Geller, H. et al., "Acid Rain and Electricity Conservation," American Council for an Energy-Efficient Economy, Washington, 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, FD and Parris, KM, "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 UEC: All Dwellings," p 3-19.

Gulf (86)

Listed in Sebold, FD and Parris, KM, "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 UEC: All Dwellings," p 3-19.

NPC (86)

Listed in Sebold, FD and Parris, KM, "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 UEC: All Dwellings," p 3-19.

NYSEG (86)

Listed in Sebold, FD and Parris, KM, "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 UEC: All Dwellings," p 3-19.

PG&E (86)

Listed in Sebold, FD and Parris, KM, "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 UEC: All Dwellings," p 3-19.

PG&Ea (86)

Listed in Sebold, FD and Parris, KM, "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 UEC: Single-Family Dwellings," p 3-20.

RG&E (86)

Listed in Sebold, FD and Parris, KM, "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 UEC: All Dwellings," p 3-19. A footnote in the table indicated this cooking UEC was without microwave.

TVA (86)

Listed in Sebold, FD and Parris, KM, "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 UEC: All Dwellings," p 3-19.

Adjusted

This is energy consumption using the adjusted annual useful cooking-energy output for gas cooktops and self-cleaning and standard ovens weighted by sales data supplied by Wayne Hamilton, AHAM, 3/30/90 in a 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 without 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 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 Gas Ovens," using the adjusted annual useful cooking-energy output.

These values are the annual energy consumption for an gas cooktop with electronic ignition and also a standard gas oven. 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 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 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 are 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)

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.

SoCal (84 w/o pilots)

Conditional demand estimates for single-family homes in Southern California. These data are 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 UECs 20-Year Weather," p 4-8. The data for units without 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)

Conditional demand estimates for single family homes in Southern California. These data are 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 UECs 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)

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)

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 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 costs. 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.

Table A.4 Total Manufacturing Costs for Kitchen Ranges and Ovens (by Design Options)

Electric Cooktop, Coil Element

Std. 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	1	0 + Imp Contact Conductance	2.28	0.00	0.00	0.00	0.00	2.28	71.34	35%
3,4,5	2	1 + Reflective Surfaces	0.00	2.60	0.10	0.00	0.34	3.03	74.37	55%

Electric Cooktop, Smooth Element

Std. 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: Solid Disk Element	55.88	8.31	0.00	0.00	24.94	-	89.14	5%
4	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

Std. 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	1	0 + Red. Burner Excess Air	0.00	0.78	0.00	0.00	0.00	0.78	89.87	20%
2	2	1 + Electronic Ignition	13.00	1.58	0.14	0.00	0.07	14.79	104.66	5%
	3	2 + Sealed Burners	20.00	0.00	0.00	0.00	0.00	20.00	124.66	20%
3,4,5	4	3 + Reflective Surfaces	4.20	0.00	0.45	0.00	1.49	6.14	130.80	55%
	5	4 + Thermostatic Burner	16.80	0.00	0.05	0.00	0.08	16.93	147.73	20%

Electric Oven, Non-Self-Cleaning

Std. 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	0 + Remove Door Window	0.00	0.00	0.00	0.00	0.00	0.00	146.17	5%
	2	1 + Improved Door Seals	0.89	0.00	0.13	0.00	0.07	1.09	147.26	25%
	3	2 + Reduced Vent Rate	1.56	0.00	0.05	0.00	0.02	1.63	148.89	90%
1	4	3 + Reflective Surfaces	1.05	0.00	0.15	0.00	0.29	1.49	150.38	55%
2	5	4 + Added Insulation	3.34	0.40	0.48	0.00	0.03	4.24	154.62	50%
	6	5 + Forced Convection	4.93	0.82	0.00	0.00	2.47	8.22	162.84	50%
3,4	7	6 + Reduced Thermal Mass	2.00	0.00	0.30	0.00	0.14	2.44	165.28	55%
	8	7 + Improved Insulation	2.90	0.20	0.00	0.00	0.11	3.22	168.49	50%
	9	8 + Bi-Radiant Oven	37.50	6.25	0.00	0.00	18.75	62.50	230.99	50%
	10	9 + Oven Separator	9.00	2.22	0.28	0.08	0.17	11.75	242.74	50%
5	11	10 + Reduced Cond. Losses	2.63	0.00	0.56	0.00	0.36	3.55	246.29	55%

Electric Oven, Self-Cleaning

Std. Level	Design No.	Design Options	Mat. Cost	Labor Cost	Tool. Cost	Ship. Cost	Ind. Cost	Total Incr.	Total Cost	Uncert
1	0	Baseline	111.09	18.52	0.00	0.00	55.55	-	185.15	5%
	1	0 + Remove Door Window	0.00	0.00	0.00	0.00	0.00	0.00	185.15	5%
2	2	1 + Reflective Surfaces	1.05	0.00	0.25	0.00	0.53	1.83	186.98	55%
3	3	2 + Forced Convection	5.69	0.95	0.00	0.00	2.85	9.49	196.47	50%
	4	3 + Added Insulation	3.34	0.40	0.48	0.00	0.03	4.24	200.71	50%
4	5	4 + Reduced Thermal Mass	2.00	0.00	0.60	0.00	0.28	2.88	203.59	55%
	6	5 + Bi-Radiant Oven	37.50	6.25	0.00	0.00	18.75	62.50	266.09	50%
	7	6 + Oven Separator	9.00	2.22	0.56	0.08	0.34	12.20	278.29	45%
5	8	7 + Reduced Cond. Losses	2.63	0.00	1.07	0.00	0.67	4.37	282.66	55%

Gas Oven, Non-Self-Cleaning

Std. 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	0 + Remove Door Window	0.00	0.00	0.00	0.00	0.00	0.00	154.80	5%
1	2	1 + Electric Ignition	5.00	0.79	0.08	0.00	0.05	5.93	160.72	5%
	3	2 + Reduced Vent Rate	1.56	0.00	0.05	0.00	0.02	1.63	162.35	90%
	4	3 + Improved Door Seals	0.83	0.00	0.17	0.00	0.09	1.09	163.44	25%
	5	4 + Reflective Surfaces	1.05	0.00	0.16	0.00	0.31	1.52	164.96	55%
2	6	5 + Added Insulation	3.34	0.40	0.48	0.00	0.03	4.24	169.20	50%
	7	6 + Forced Convection	5.57	0.93	0.00	0.00	2.79	9.29	178.49	50%
	8	7 + Reduced Thermal Mass	2.00	0.00	0.33	0.00	0.15	2.48	180.97	55%
3,4	9	8 + Improved Insulation	3.33	0.09	0.00	0.00	0.15	3.58	184.55	45%
	10	9 + Oven Separator	20.00	5.78	2.29	0.00	0.20	28.26	212.81	90%
5	11	10 + Reduced Cond. Losses	2.63	0.00	0.61	0.00	0.39	3.63	216.44	55%

Gas Oven, Self-Cleaning

Std. Level	Design No.	Design Options	Mat. Cost	Labor Cost	Tool. Cost	Ship. Cost	Ind. Cost	Total Incr.	Total Cost	Uncert
1	0	Baseline	132.15	22.03	0.00	0.00	66.08	-	220.26	10%
	1	0 + Remove Door Window	0.00	0.00	0.00	0.00	0.00	0.00	220.26	5%
2	2	1 + Improved Door Seals	0.78	0.00	0.23	0.00	0.11	1.12	221.38	25%
3	3	2 + Reflective Surfaces	1.05	0.00	0.25	0.00	0.53	1.83	223.21	55%
	4	3 + Added Insulation	3.34	0.40	0.48	0.00	0.03	4.24	227.45	50%
4	5	4 + Reduced Thermal Mass	2.00	0.00	0.60	0.00	0.28	2.88	230.33	55%
	6	5 + Forced Convection	6.61	1.10	0.00	0.00	3.30	11.01	241.34	50%
	7	6 + Reduced Cond. Losses	2.63	0.00	1.07	0.00	0.67	4.37	245.71	55%
5	8	7 + Oven Separator	29.00	7.62	8.90	0.00	0.45	45.97	291.68	90%

Microwave Ovens

Std. Level	Design No.	Design Options	Mat. Cost	Labor Cost	Tool. Cost	Ship. Cost	Total Incr.	Total Cost	Uncert
0	0	Baseline	-	-	-	-	-	120.00	20%
1	1	0 + Eff. Power Supply	5.00	0.00	0.00	0.00	5.00	125.00	20%
2	2	1 + Eff. Fan	1.05	0.00	0.00	0.00	6.05	126.05	20%
3	3	2 + Modified Wave Guide	1.50	0.00	0.35	0.00	7.90	127.90	20%
4	4	3 + Improved Magnetron	12.50	0.00	0.00	0.00	20.40	140.40	20%
5	5	4 + Reflective Surfaces	16.40	0.00	0.00	0.00	36.80	156.80	20%

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

The complete input listing is available on electronic medium in ASCII format. The input database includes demographic, economic, and engineering data.

The following is the regular LBL-REM input for cooktops, ovens, and microwave ovens.

For standards cases, simply replace the input values for two variables in each class of each product regulated. The two variables are labelled: "first year for standard" and "UEC of standard". For example, for cooktop standards taking effect in 1996, change the lines "first year for standard = 2031" to "first year for standard = 1996" and enter the appropriate maximum UEC values in the lines "UEC of standard" for each class.

Cooktop

```
total saturation      = 1.00
elec price multiplier = 1.04
gas price multiplier  = 1.20
ncalc                = 2
ndr1 (1, read drate & curve) = 1
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	
13.84	9.24	0.00	0.00	0.00	** SF **
13.77	9.35	0.00	0.00	0.00	** MF **
13.69	8.68	0.00	0.00	0.00	** MB **

----- Purchase price of a reference unit (\$1990) -----

1	2	3	4	5	
375.26	219.91	0.00	0.00	0.00	** SF **
375.26	219.91	0.00	0.00	0.00	** MF **
375.26	219.91	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	1.00	0.00	0.00	** re **
1.00	1.00	1.00	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	** MB **

----- 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 **
0.250	0.740	0.000	0.000	0.000	0.010	** MB **

----- Marginal Saturations for New Houses - cn(m=2) -----

1	2	3	4	5	6	
0.790	0.200	0.000	0.000	0.000	0.010	** SF **
0.870	0.120	0.000	0.000	0.000	0.010	** MF **
0.510	0.470	0.000	0.000	0.000	0.020	** MB **

----- Historical Shipments (from 1980 to 30 years back) -----

1 Electric Ranges/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 Ranges/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	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 */

----- Real Interest Rate for calc of Price Elast. (for 5 fuel types) -----

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 */

----- Discount Rates for Replacement Units (m=1) -----

1	2	3	4	5	
0.348	-0.029	0.000	0.000	0.000	** SF **
0.346	-0.028	0.000	0.000	0.000	** MF **
0.344	-0.035	0.000	0.000	0.000	** MB **

----- Discount Rates for New Units (m=2) -----

1	2	3	4	5	
0.348	-0.029	0.000	0.000	0.000	** SF **
0.346	-0.028	0.000	0.000	0.000	** MF **
0.344	-0.035	0.000	0.000	0.000	** MB **

----- Cost-Efficiency Curve Parameters -----

1	2	3	4	5	
0.8621	0.5668	0.5668	0.00	0.00	** einf **
10.4137	2.3001	2.3001	0.00	0.00	** ealfa **

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        = 0.20
first year to forecast UEC = 1989
first year for standard = 2031
UEC of standard      = 271.1
conversion (Kwh-MMBTU&usage) = .003412
  
```

----- Historical energy factors

1981	1982	1983	1984	1985	1986	1987	1988	1989
------	------	------	------	------	------	------	------	------

.772 .772 .772 .772 .772 .772 .772 .772 .772

----- Adjusted volumes (1981-2030) (271.0 * .772 / 365)

0.5734 0.5734 0.5734 0.5734 0.5734 0.5734 0.5734 0.5734 0.5734 0.5734
 0.5734 0.5734 0.5734 0.5734 0.5734 0.5734 0.5734 0.5734 0.5734 0.5734
 0.5734 0.5734 0.5734 0.5734 0.5734 0.5734 0.5734 0.5734 0.5734 0.5734
 0.5734 0.5734 0.5734 0.5734 0.5734

----- Fraction of market share (1981-2030)

1 = 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
179.96	271.10
184.75	260.20
191.20	257.70

----- Shipment Distribution

EF	Units
.772	1.

----- the 2nd class -----

class id# = 37
 class name = Smth (Electric Cooktop, Smooth Element)
 discount rate = 0.20
 first year to forecast UEC = 1989
 first year for standard = 2031
 UEC of standard = 293.7
 conversion (Kwh-MMBTU&usage) = .003412

----- Historical energy factors

1981	1982	1983	1984	1985	1986	1987	1988	1989
.713	.713	.713	.713	.713	.713	.713	.713	.713

----- Adjusted volumes (1981-2030) (293.7 * .713 / 365)

0.5737 0.5737 0.5737 0.5737 0.5737 0.5737 0.5737 0.5737 0.5737 0.5737
 0.5737 0.5737 0.5737 0.5737 0.5737 0.5737 0.5737 0.5737 0.5737 0.5737
 0.5737 0.5737 0.5737 0.5737 0.5737 0.5737 0.5737 0.5737 0.5737 0.5737
 0.5737 0.5737 0.5737 0.5737 0.5737

----- Fraction of market share (1981-2030)

1 = 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
289.75	293.70
636.99	289.20
874.50	258.50

----- Shipment Distribution

Kwh	Units
.713	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	= 0.59
first year to forecast UEC	= 1989
first year for standard	= 2031
UEC of standard	= 3.7581
conversion (usage)	= 1.000

----- Historical energy factors

1981	1982	1983	1984	1985	1986	1987	1988	1989
.188	.188	.188	.188	.188	.188	.188	.188	.188

----- Adjusted volumes (1981-2030) (3.8866 * .188 / 365)

.002002	.002002	.002002	.002002	.002002	.002002	.002002	.002002	.002002	.002002	.002002
.002002	.002002	.002002	.002002	.002002	.002002	.002002	.002002	.002002	.002002	.002002
.002002	.002002	.002002	.002002	.002002	.002002	.002002	.002002	.002002	.002002	.002002
.002002	.002002	.002002	.002002	.002002						

----- Fraction of market share (1981-2030)

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	1.00	1.00	1.00						

----- UEC (MMBTU) & Purchase Price (\$1990) data

Price	MMBTU
219.91	3.8866 0.0000
221.54	3.7581 0.0000
333.29	1.7083 0.0000
377.11	1.6292 0.0000
387.99	1.6274 0.0000

----- Shipment Distribution

EF Units
 .188 1.
 Oven
 total saturation = 1.00
 elec price multiplier = 1.04
 gas price multiplier = 1.20
 ncalc = 2
 ndr1 (1, read drate & curve) = 1
 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	
13.84	9.24	0.00	0.00	0.00	** SF **
13.77	9.35	0.00	0.00	0.00	** MF **
13.69	8.68	0.00	0.00	0.00	** MB **

----- Purchase price of a reference unit (\$1990) -----

1	2	3	4	5	
375.26	786.49	0.00	0.00	0.00	** SF **
375.26	786.49	0.00	0.00	0.00	** MF **
375.26	786.49	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	1.00	** re **
1.00	1.00	0.00	0.00	1.00	** recap**

----- Base Year Saturations - c70 -----

1	2	3	4	5	6	
0.600	0.380	0.000	0.000	0.000	0.020	** SF **
0.480	0.500	0.000	0.000	0.000	0.020	** MF **
0.460	0.510	0.000	0.000	0.000	0.030	** MB **

----- Marginal Saturations for Replacement Units - cn(m=1) -----

1	2	3	4	5	6	
0.570	0.420	0.000	0.000	0.000	0.010	** SF **
0.380	0.600	0.000	0.000	0.000	0.020	** MF **
0.270	0.700	0.000	0.000	0.000	0.030	** MB **

----- Marginal Saturations for New Houses - cn(m=2) -----

1	2	3	4	5	6	
0.760	0.210	0.000	0.000	0.000	0.030	** SF **
0.840	0.115	0.000	0.000	0.000	0.045	** MF **
0.495	0.460	0.000	0.000	0.000	0.045	** 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 */

----- Real Interest Rate for calc of Price Elast. (for 5 fuel types) -----

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 */

----- Discount Rates for Replacement Units (m=1) -----

1	2	3	4	5	
0.348	-0.029	0.000	0.000	0.000	** SF **
0.346	-0.028	0.000	0.000	0.000	** MF **
0.344	-0.035	0.000	0.000	0.000	** MB **

----- Discount Rates for New Units (m=2) -----

1	2	3	4	5	
0.348	-0.029	0.000	0.000	0.000	** SF **
0.346	-0.028	0.000	0.000	0.000	** MF **
0.344	-0.035	0.000	0.000	0.000	** MB **

----- Cost-Efficiency Curve Parameters -----

1	2	3	4	5	
0.8621	0.5668	0.00	0.00	0.00	** einf **
10.4137	2.3001	0.00	0.00	0.00	** calfa **

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 = 0.61
first year to forecast UEC = 1989
first year for standard = 2031
UEC of standard = 966.5
conversion (Kwh-MMBTU&usage) = .003412

----- Historical energy factors

1981	1982	1983	1984	1985	1986	1987	1988
.109	.109	.109	.109	.109	.109	.109	.109

----- Adjusted volumes (1981-2030) (327.2 * .109 / 365)

.09771	.09771	.09771	.09771	.09771	.09771	.09771	.09771	.09771	.09771
.09771	.09771	.09771	.09771	.09771	.09771	.09771	.09771	.09771	.09771
.09771	.09771	.09771	.09771	.09771	.09771	.09771	.09771	.09771	.09771
.09771	.09771	.09771	.09771	.09771					

----- Fraction of market share (1981-2030)

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
395.43	327.20
395.43	315.90

397.96	298.70
401.21	287.00
404.27	278.30
414.16	256.80
431.63	223.80
436.73	217.50
444.39	211.30
577.74	161.20
603.12	157.60
609.23	157.30

----- Shipment Distribution

EF	Units
.109	1.

----- the 2nd class -----

class id#	= 68
class name	= EwSC (Electric Oven, with-Self-Cleaning)
discount rate	= 0.14
first year to forecast UEC	= 1988
first year for standard	= 2031
UEC of standard	= 398.9
conversion (Kwh-MMBTU&usage)	= .003412

----- Historical energy factors

1981	1982	1983	1984	1985	1986	1987	1988
.102	.102	.102	.102	.102	.102	.102	.102

----- Adjusted volumes (1981-2030) (346.7 * .102 / 365)

.096886	.096886	.096886	.096886	.096886	.096886	.096886	.096886	.096886	.096886	.096886
.096886	.096886	.096886	.096886	.096886	.096886	.096886	.096886	.096886	.096886	.096886
.096886	.096886	.096886	.096886	.096886	.096886	.096886	.096886	.096886	.096886	.096886
.096886	.096886	.096886	.096886	.096886	.096886	.096886	.096886	.096886	.096886	.096886

----- Fraction of market share (1981-2030)

1 =	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	0.56	0.56	0.56						

----- UEC (Kwh) & Purchase Price (\$1990) data

Price	Kwh
595.54	346.70
595.54	336.90
600.50	328.70
628.89	287.30
642.49	273.20
651.05	266.80
838.83	212.70
871.78	209.40

881.90 209.20

----- Shipment Distribution

Kwh Units
.102 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 = 0.49
first year to forecast UEC = 1989
first year for standard = 2031
UEC of standard = 3.728
conversion (usage) = 1.000

----- Historical energy factors

1981	1982	1983	1984	1985	1986	1987	1988	1989
.035	.037	.039	.041	.043	.045	.047	.049	.051

----- Adjusted volumes (1981-2030) (3.5801 * .035 / 365)

.000343	.000343	.000343	.000343	.000343	.000343	.000343	.000343	.000343	.000343
.000343	.000343	.000343	.000343	.000343	.000343	.000343	.000343	.000343	.000343
.000343	.000343	.000343	.000343	.000343	.000343	.000343	.000343	.000343	.000343
.000343	.000343	.000343	.000343	.000343	.000343	.000343	.000343	.000343	.000343

----- Fraction of market share (1981-2030)

1 = 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	
450.61	3.5801	0.0000
450.61	3.4994	0.0000
464.45	1.8869	0.1631
469.19	1.6966	0.1631
472.52	1.5881	0.1631
476.73	1.4727	0.1631
487.17	1.2181	0.1631
507.82	1.0238	0.1771
512.64	0.9986	0.1771
519.61	0.9670	0.1771

603.93 0.9002 0.1771
 611.70 0.8956 0.1771

----- Shipment Distribution

EF	Units
.035	.369
.061	.631

----- the 2nd class -----

class id# = 70
 class name = GwSC (Gas Oven, with-self-cleaning)
 discount rate = 0.32
 first year to forecast UEC = 1988
 first year for standard = 2031
 UEC of standard = 3.728
 conversion (usage) = 1.000

----- Historical energy factors

1981	1982	1983	1984	1985	1986	1987	1988
.060	.060	.060	.060	.060	.060	.060	.060

----- Adjusted volumes (1981-2030) (3.8866 * .188 / 365)

.000354	.000354	.000354	.000354	.000354	.000354	.000354	.000354	.000354	.000354
.000354	.000354	.000354	.000354	.000354	.000354	.000354	.000354	.000354	.000354
.000354	.000354	.000354	.000354	.000354	.000354	.000354	.000354	.000354	.000354
.000354	.000354	.000354	.000354	.000354					

----- Fraction of market share (1981-2030)

1 = 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	
744.14	1.8821	0.2740
744.14	1.8151	0.2740
748.41	1.7094	0.2740
753.39	1.6160	0.2740
771.40	1.4052	0.2740
778.87	1.3652	0.2740
812.72	1.1816	0.2883
827.36	1.1772	0.2883
1003.29	1.1323	0.2883

----- Shipment Distribution

EF	Units
.060	1.

MWv Oven
 total saturation = 1.00
 elec price multiplier = 1.04
 gas price multiplier = 1.00
 ncalc = 2
 ndr1 (1, read drate & curve) = 1
 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	
3.105	0.00	0.00	0.00	0.00	** SF **
3.105	0.00	0.00	0.00	0.00	** MF **
3.105	0.00	0.00	0.00	0.00	** MB **

----- Purchase price of a reference unit (\$1990) -----

1	2	3	4	5	
185.98	0.00	0.00	0.00	0.00	** SF **
185.98	0.00	0.00	0.00	0.00	** MF **
185.98	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 **
0.585	0.000	0.000	0.000	0.000	0.415	** MF **
0.575	0.000	0.000	0.000	0.000	0.425	** MB **

----- Historical Shipments (from 1980 to 30 years back) -----

1 Electric Ranges/Ovens

3608.	2807.	2501.	2157.	1749.	1052.	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 */

----- Real Interest Rate for calc of Price Elast. (for 5 fuel types) -----

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 */

----- Discount Rates for Replacement Units (m=1) -----

1	2	3	4	5	
0.348	0.000	0.000	0.000	0.000	** SF **
0.346	0.000	0.000	0.000	0.000	** MF **
0.344	0.000	0.000	0.000	0.000	** MB **

----- Discount Rates for New Units (m=2) -----

1	2	3	4	5	
0.348	0.000	0.000	0.000	0.000	** SF **
0.346	0.000	0.000	0.000	0.000	** MF **
0.344	0.000	0.000	0.000	0.000	** MB **

----- Cost-Efficiency Curve Parameters -----

1	2	3	4	5	
0.8621	0.00	0.00	0.00	0.00	** einf **
10.4137	0.00	0.00	0.00	0.00	** ealfa**

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
first year to forecast UEC = 1989
first year for standard = 2031
UEC of standard = 966.5
conversion (Kwh-MMBTU&usage) = .003412

----- Historical energy factors

1981	1982	1983	1984	1985	1986	1987	1988
.540	.540	.540	.540	.540	.540	.540	.540

----- Adjusted volumes (1981-2030) (271.0 * .772 / 365)

.399452	.399452	.399452	.399452	.399452	.399452	.399452	.399452	.399452	.399452	.399452
.399452	.399452	.399452	.399452	.399452	.399452	.399452	.399452	.399452	.399452	.399452
.399452	.399452	.399452	.399452	.399452	.399452	.399452	.399452	.399452	.399452	.399452
.399452	.399452	.399452	.399452	.399452						

----- Fraction of market share (1981-2030)

1 = 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
185.98	270.00
191.47	239.00
192.76	236.00
195.12	233.30
211.36	230.00
232.78	228.20

----- Shipment Distribution

EF	Units
.540	1.

APPENDIX C. LBL MANUFACTURER IMPACT MODEL: KITCHEN RANGES, OVENS, AND MICROWAVE OVENS

C.1 INTRODUCTION

The Lawrence Berkeley Laboratory Manufacturer Impact Model (LBL-MIM) collects all the calculations necessary to determine the impact of a change in appliance efficiency standards on an industry's profitability and scale of operation into one spreadsheet. Volume A, Appendix C, provides an overview and description of the LBL-MIM. There is a description of the economic theory and a discussion of each of the model's modules. In this appendix, the LBL-MIM input data and model runs for the analysis of kitchen ranges and ovens and microwave ovens are described together.

C.1.1 Engineering Cost Data

The source of the engineering data is the Engineering Analysis performed in Chapter 1. The data came from manufacturers of these products and/or discussions with industry consultants and other studies. The engineering data used as inputs to the model consist of several components:

1. The incremental unit variable cost incurred by the manufacturer for each of the design options such as raw materials, direct labor, purchased parts, and increased transportation costs, that increases the efficiency of the appliance. The incremental variable cost is listed for each design option for each product class.
2. The annual unit energy consumption (UEC) associated with each design option for each product class.
3. 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 as one figure for each design option requiring capital expenditures; the single figure covers all of the product classes.

The annual UECs listed in the Engineering module of the LBL-MIM are based on the estimated actual usage of the appliances and thus probably differ from the UEC as determined by the test procedure. The energy used per cycle is the same, but the number of cycles run per year differs. This modification is done because the annual UEC as determined by the test procedure is based on an established number of cycles run per year which differs from the actual usage. LBL-REM provides the estimates of actual appliance usage.

The engineering input data are also listed for each standards level being analyzed (a 1990 calibration case, a 1996 base case using the 1990 standards, and standards Levels 1, 2, 3, etc. 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 standards levels instead. The engineering data used as inputs to the LBL-MIM 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. For a thorough description of the collection and meaning of the engineering data, see the Engineering Analysis.

C.1.2 Industry Market Data

Industry Shipments

These data include annual industry shipments for the 1990 calibration case, the 1996 base case (using the 1990 standards), and the 1996 shipments for each of the standards levels. The 1989 shipments figure is based on data from "Share of Market," February 1990, *Appliance Manufacturer*.

Elasticities

Price and operating cost elasticities determine the effect on shipments of changes in appliance price and operating cost. For cooktops, the price elasticity is estimated to be -0.15. The consumer discount rate is estimated to be 36.8%, which gives an operating cost elasticity of -0.09. For ovens, the price elasticity is estimated to be -0.15 and the discount rate is estimated to be 37.48%, which gives an operating cost elasticity of -0.01. For microwave ovens, the price elasticity is estimated to be -0.6 and the discount rate is estimated to be 250%, which gives an operating cost elasticity of -2.31. The source of data is LBL. Because these data are very important, a sensitivity analysis using different elasticities is done.

Product Class Market Share

Each of the product classes has a share of the total kitchen range and oven market, and the market share, or unit sales, for each product class is an input to the model. For cooktops, the market is composed of 48% electric-coil and 43% conventional gas with the balance for electric-smooth cooktops. For ovens, conventional electric ovens are 26% of the market, electric self-cleaning are 33%, and gas conventional ovens are 32%. The balance is for gas self-cleaning ovens. There is only one product class for microwave ovens. The source of data is a 24 August 1990 private communication from the Association of Home Appliance of Manufacturers.

Markups

Manufacturers charge different markups over variable cost for different product classes, resulting in different profit margins for different product classes. For cooktops, the estimated markups range from 1.13 for an electric-smooth cooktop to 1.39 for a conventional gas cooktop.

Electric-smooth cooktops are estimated to have a markup of 1.38. For ovens, estimated markups range from 1.31 for conventional electric ovens, to 1.93 for self-cleaning gas ovens. The estimated markup for microwave ovens is 1.40.

Initial prices

The 1989 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 LBL.

Energy price

This figure is the ratio of the price of a 1990 kWh to a 1996 kWh. The source is the LBL-REM. Industry market data appear on the Cost, Sales, and Revenues pages of the model.

C.1.3 Financial Input Data

Financial Inputs

The financial inputs for kitchen ranges and ovens 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 ¹	6.8%	MIM calc. from public financial data ²
Interest rate on debt ¹	2.5%	MIM calc. from public financial data
Interest lost in cash ¹	1.0%	MIM calc. from public financial data
Rate of depreciation	17.7%	Public financial data
Tax rate	34.0%	Tax law

¹Cost of capital and interest rate are *real* rather than nominal.

²Public financial data include data from Value Line, Standard and Poors, Moody's, individual company annual reports, and economic reports.

Table C.2 Other Financial Costs

Variable	Value	Source
Cash	4.6%	Public financial data
Inventory and receivables	30.7%	Public financial data
Net depreciable assets	15.1%	Public financial data
General and administrative expenses	13.9%	Public financial data
Engineering expense	1.2%	Public financial data and industry sources ¹

¹Industry sources include consultants under contract to LBL and discussions with industry representatives.

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

Variable	Value	Source
Fixed part of all costs and depr. assets	10.0%	Industry sources
Fixed part of one-time capital costs	15.0%	Industry sources
Economic profit	0.0%	MIM est. from financial data
Debt/equity ratio	112.6%	Public financial data
Markup on typical model	1.37	Industry sources
Ratio of highest to lowest markup	1.00	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	8 years	MIM calculation
Percent additional 1-X capital	100%	MIM estimate
Age of replaced capital	6 years	Public financial data

The expenditure schedule above lists the costs incurred over time for preparations to meet the new standards. A percentage of the total cost is attributed to each year before the standards go into effect since that is when these expenses will be incurred.

C.2 LBL-MIM INPUTS AND OUTPUTS SHOWING THE PRIMARY SCENARIO

Table C.5 Cooktops Version of LBL-MIM

Control Panel

COOKTOPS CONTROL FACTORS	Scenario: Primary		Standard Level = 1		
	Input Value	Cntrl	Vari- ation	Progrm Value	Name
Price Elasticity	-0.150	0.98	100%	-0.339	IPE
Consumer Discount Rate	36.79%	-1.64	100%	9.41%	RD
Equity Cost of Capital	0.068	0.48	10%	0.071	ECC
Economic Profit	0.018	-1.66	1%	0.002	EP
L-R Fixed Part of Costs & Assets	0.088	0.86	50%	0.133	FCA
L-R Fixed Part of 1-X Cap. Cost	0.059	1.15	60%	0.111	F1X
One-Time Capital Costs	0.000	1.48	20%	0.000	CC.N
Unit Variable Cost Increase	\$0.34	-1.66	30%	0.206	dVC.N
Elasticity Curve Parameter	0.000	-0.80	30%	-0.240	ro.N
Short Run Price Response to Demand	0.157	-1.08	76%	0.037	SRPR
SUMMARY	NAECA	NEW	PRVIOUS	NEW	
	BASE	L-RUN	CHANGE	S-RUN	
Shipments	1.01	1.02	1.17%	7.10%	1.02
Price	\$99.01	\$99.01	0.00%	-18.13%	\$99.06
Revenue (in \$M)	99.68	100.85	1.17%	-12.31%	100.88
Net Income	4.51	4.52	0.02	-0.12	4.55
ROE	7.31%	7.25%	-0.05%	-2.17%	7.29%
Trys =			2.00		

Table C.6 Cooktops Version of LBL-MIM

The Accounting Module

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

	1990	BASE '96	NEW '96	CHANGE
Revenue	99.68	99.68	100.85	1.2%
Expenses				
Cost of Goods Sold	78.96	78.96	80.10	1.4%
Selling & G & A	9.12	9.26	9.26	0.1%
Engineering	0.75	0.76	0.76	0.1%
Depreciation	3.68	3.68	3.68	NA
1-X Depreciation	0.00	0.00	0.00	NA
Total Expenses	92.50	92.66	93.80	1.2%
Earnings Before Interest & Taxes	7.18	7.02	7.05	0.4%
Interest	0.35	0.20	0.20	1.1%
Earnings Before Taxes	6.83	6.83	6.85	0.4%
Taxes	2.32	2.32	2.33	0.4%
Net Income	4.51	4.51	4.52	0.4%
Gross Margin	20.79%	20.79%	20.58%	-1.00%
Return on Sales	4.52%	4.52%	4.49%	-0.8%
Total Assets	77.11	77.11	77.98	1.1%
Return on Assets (w/intrst taxed)	6.14%	6.01%	5.97%	0.0
Equity	61.69	61.69	62.38	1.1%
Return on Equity	7.31%	7.31%	7.25%	-0.1
ECONOMIC ANALYSIS				
	1990	BASE '96	NEW '96	CHANGE
INCOME				
Shipments	1.01	1.01	1.02	1.2%
Price	\$99.01	\$99.01	\$99.01	0.0%
Revenue	99.68	99.68	100.85	1.2%
EXPENSE (w/ INTEREST)				
Fixed Costs	8.82	8.82	8.82	-9.2%
Variable Costs (w/ Q)	82.78	82.78	8.83	-11.5%
Total Expenses	0.00	91.60	91.60	-10.9%
ASSETS				
Cash	12.66	12.66	12.59	-10.8%
Inventories	44.23	44.23	44.75	1.2%
Depreciable	-870.12	-837.12	-742.77	-11.3%
Total Assets	77.11	77.11	77.98	1.1%

Table C.7 Cooktops Version of LBL-MIM

The Monte Carlo Module

MONTE CARLO DETERMINATION OF STANDARD ERRORS OF ESTIMATES.							
		Seconds/iteration =				1.54	time
		Iterations to go =				0.00	nn
COOKTOPS (COM)		Sample Size =				49.00	
curr	Value	%dQ	%dP	%dR	%dNI	dROE.N	dROE.S
forms	Means	0.23%	0.27%	0.50%	-0.71%	-0.03%	0.01%
	Std. Dev	0.35%	0.12%	0.34%	3.09%	0.04%	0.08%
	History	0.01	0.00	0.01	0.02	0.00	0.00
	...	0.00	0.00	0.00	-0.02	0.00	0.00
	Range	0.00	0.00	0.00	-0.01	0.00	0.00
	Name	0.00	0.00	0.00	0.01	0.00	0.00
	Is	0.00	0.00	0.00	-0.10	0.00	0.00
	Carlo	0.00	0.00	0.00	0.00	0.00	0.00
		0.01	0.00	0.01	0.04	0.00	0.00
		0.02	0.00	0.02	0.07	0.00	0.00
		0.00	0.00	0.00	-0.02	0.00	0.00
		0.00	0.00	0.00	-0.01	0.00	0.00
		0.00	0.00	0.00	-0.03	0.00	0.00
		0.00	0.00	0.00	-0.01	0.00	0.00
		0.00	0.00	0.00	-0.01	0.00	0.00
		0.00	0.00	0.00	-0.01	0.00	0.00
		0.00	0.00	0.00	-0.06	0.00	0.00
		0.00	0.00	0.00	-0.03	0.00	0.00
		0.00	0.00	0.00	0.00	0.00	0.00
		0.01	0.00	0.01	-0.05	0.00	0.00
		0.01	0.01	0.01	0.02	0.00	0.00
		0.00	0.00	0.00	-0.02	0.00	0.00
		0.00	0.00	0.00	-0.05	0.00	0.00
		0.00	0.00	0.00	-0.06	0.00	0.00
		0.00	0.00	0.00	-0.02	0.00	0.00
		0.00	0.00	0.00	-0.01	0.00	0.00
		0.00	0.01	0.01	0.00	0.00	0.00
		0.00	0.00	0.00	0.00	0.00	0.00
		0.00	0.00	0.00	0.02	0.00	0.00
		0.01	0.00	0.01	-0.03	0.00	0.00
		0.00	0.00	0.00	0.00	0.00	0.00
		0.00	0.00	0.00	0.00	0.00	0.00
		0.00	0.00	0.01	0.00	0.00	0.00
		0.00	0.00	0.01	0.03	0.00	0.00
		0.00	0.00	0.01	0.01	0.00	0.00

Table C.8 Cooktops Version of LBL-MIM

The Engineering Inputs Module

Increment in Additional UVC by Level and Class						
Baseline	0	1	2	3	4	5
El-Coil	62.9	2.3	2.8			
El-Smooth	81.7	256.3	151.0	43.8		
Gas	81.1	0.8	14.6	20.0	5.2	16.9
VCS.E Additional UVC. (Above Level 0 cost). Lots of Branches						
CLS	0	1	2	3	4	5
0	0	2	5	0	0	0
1	0	256	151	44	0	0
2	0	1	15	35	41	58
Electricity in Kw Hrs /Yr: Gas in KBTU						
	0	1	2	3	4	5
El-Coil	271	260	258	0	0	0
El-Smooth	294	259	289	305	0	0
Gas	3887	3758	1708	1629	1627	1627
KWS.E						
	0	1	2	3	4	5
El-Coil	22	21	21	0	0	0
El-Smooth	24	21	24	25	0	0
Gas	22	21	10	9	9	9
Capital cost / unit / 7						
	0	1	2	3	4	5
El-Coil	6.2	0.0	0.2	0	0	0
El-Smooth	7.5	25.3	14.9	4.3	0	0
Gas	8.0	0.0	0.2	0.0	0.9	0.1
CC.E Additional CC./7 (Above Level 0 cost.): Lots of Branches						
CLS	0	1	2	3	4	5
0	0.0	0.0	0.2	0	0	0
1	0.0	25.3	14.9	4.3	0	0
2	0.0	0.0	0.2	0.2	1.1	1.1
Additional CC *7: Lots of Branches						
	0	1	2	3	4	5
El-Coil	0	0.0	0.7	0	0	0
El-Smooth	0	15.0	8.8	2.6	0	0
Gas	0	0.0	0.5	0.5	3.2	3.4
CCEE.E	0	15	10	3	3	3

Table C.9 Cooktops Version of LBL-MIM

The Standards Level Module

LevIn prev	LEV.B	lev.N	Eng:	0 ...	9	"E _{max}	
-1	0	1	REM	-1 ...	5	"S _{max}	
1	1	1		1 ==> Stndrds	0 ==> Eng.		
SIE	SIE.B	SIE.N	Esc = QUIT				
VCS.R Additional UVC by Level and Class. (Above Base cost.)							
LEVEL -->	-1=1987	0=1996	1	2	3	4	5
El-Coil	0.00	0.00	0.00	2.28	5.11	5.11	5.11
El-Smooth	0.35	0.35	0.35	0.35	0.35	151.04	256.26
Gas	0.00	0.00	0.78	15.41	40.65	40.65	40.65
KWS.R Kw Hrs /Yr							
LEVEL -->	-1=1987	0=1996	1	2	3	4	5
El-Coil	22	22	22	21	21	21	21
El-Smooth	24	24	24	24	24	24	21
Gas	22	22	21	10	9	9	9
CC.R							
LEVEL -->	-1=1987	0=1996	1	2	3	4	5
El-Coil	0.00	0.00	0.00	0.00	0.20	0.20	0.20
El-Smooth	0.03	0.03	0.03	0.03	0.03	14.94	25.34
Gas	0.00	0.00	0.00	0.16	1.06	1.06	1.06
CCEE.R							
LEVEL -->	-1=1987	0=1996	1	2	3	4	5
Cumltv CC	0	0	5	5	5	61	71
	0.01	0.01	0.01	0.17	1.31	4.24	6.29
	1987	1996	NEW96	1987	1996	NEW96	
	VC87	VCB	VCN	KW87	KWB	KWN	
El-Coil	0	0	0	22.28	22.28	22.28	
El-Smooth	0.34	0.34	0.34	24.14	24.14	24.14	
Gas	0	0	0.78	22.11	22.11	21.38	
	1987	1996	NEW96	Weighted	Base Case	New Stds	
	CPC87	CPCB	CPCN	Op Cost	Weighted	Weighted	
					d P	d P	
El-Coil	0	0	0	10.82	0	0	
El-Smooth	0.03	0.034	0.034	2.02	0	0	
Gas	0	0	0	9.52	0	0.33	
	Wgt Fuel Cost: F			22.36	0	0.33	
					dVC.B0	dVC.NO	

Table C.10 Cooktops Version of LBL-MIM

The Costs, Sales, and Revenue Module

							aa	100
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 (1990)								
Indst	Relatv	----- Firm -----						
Ship.	Ship.	Ship.	Price	Rev.				Weighted
		Q%	Q.1	P.1/Range	R.1	m.1	UVC.1	"UVC
El-Coil	2.44	0.49	0.49	86.10	42.09	1.13	76.24	37.02
El-Smooth	0.42	0.08	0.08	111.87	9.45	1.39	80.59	6.76
Gas	2.17	0.43	0.43	111.07	48.14	1.38	80.48	34.65
TOTAL S	5.03	20.00%	1.01	\$99	99.68	1.26	20.00%	78.43
	"TS.0	"Q.CV	Q.0	P.0	R		"P.CV	UVC
BASE CASE (1996)								
	Rule-of-	Rule-of-			Op Cost	Weightd		
	Thb d P	Thb Price		Pi.B	Ratio	OpCst-R	Qi.B	Ri.B
El-Coil	0.00	42.09	0	\$86	1.00	0.49	0.4889	42.09
El-Smooth	0.00	9.45	0	\$112	1.00	0.08	0.0844	9.45
Gas	0.00	48.14	0	\$111	1.00	0.43	0.4334	48.14
TOTALS	0.00	99.68	0	99.0	99.68	0.00	1.0067	99.68
	Alpha.B	Sum P (2)	Sum (3)	"P.B	Sum(Ri) check=R.B.	OC%.B0	"Q.B	"R.B
NEW STANDARDS CASE (1996)								
	Rule-of-	Rule-of-			% Chng	Weightd		
	Thb d P	Thb Price		Pi.N	Op Cost	OpCst-R	Qi.N	Ri.N
El-Coil	0.00	42.59	0	\$86.1	1.00	0.49	0.4946	42.59
El-Smooth	0.00	9.56	0	\$111.9	1.00	0.08	0.0854	9.56
Gas	1.08	49.18	1	\$111.1	0.97	0.42	0.4385	48.70
TOTALS	0.93	101.32	1	99.0	100.85	-0.01	1.0186	100.85
	Alpha.N	Sum P (2)	Sum (3)	"P.N	Sum(Ri) check=R.B.	OC%.N0	"Q.N	"R.N

Table C.11 Cooktops Version of LBL-MIM

The Financial Module

INPUT	NAME	VALUE	NAME	C.V. or Control Factor
RATES of COST				
After Tax Equity Cost of Capital	ECC.0	0.07	ECC.CV	10%
Interest Rate on Debt	I.0	2.50%	I.CV	100%
Interest Lost on Cash	ICash.0	0.01	ICASH.CV	100%
Rate of Depreciation	Dep.0	0.18		
Tax Rate	T.0	34.00%	T.CV	20%
ASSETS and COSTS as a PERCENT of REVENUE				
Cash	C:R.0	13%	C:R.CV	100.00%
Inventory & Receivables	IR:R.0	44%	IR:R.CV	27.19%
Depreciable Assets	DA:R.0	20%	DA:R.CV	36.89%
G & A	G&A.0	15%	G&A.CV	40.00%
Engineering	Eng	1.20%		
FIXED AND VARIABLE COST SPLIT				
Fixed Part of All Costs & Depr Assets	FDA.0	8.85%	FCA.CV	50.00%
Fixed Part of I-X Capital Cost	FIX.0	5.88%	FIX.CV	60.00%
OTHER				
Economic Profit	EP.0	1.84%	EP.CV	1.00%
Debt to Equity ratio	DER.0	25.00%	DER.CV	43.36%
Markup on typical model	"mid	38.00%		
Ratio of highest to lowest markup	"ratio	300.00%		
OUTPUT				
Depreciation	DRR	3.7%		
G&A to Overhead Ratio	G:O	92.4%		
Engineering to Overhead Ratio	E:O	7.6%		
Debt Ratio	DR	20.0%		
Equity Ratio	ER	80.0%		
Pre-Tax Equity Cost of Capital*	PECC	10.8%		
Weighted Average Cost of Capital	WACC	9.1%		
After Tax WACC	ATWACC	6.0%		
Return on Equity	ROE	7.31%		
Real ROE - Input	ROE.0	8.64%		

All interest rates and costs of capital are "real".

*When Pre-Tax ECC is used, all costs are counted tax-exempt.

Table C.12 Cooktops Version of LBL-MIM

The One-Time Cost Amortization Module

INPUTS				
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	5.86%	
Weighted CC Lead-Time Factors	0.00	0.29	0.55	0.26
Cumulative CC Lead-Time Factors		LTC.0	1.095	
exp(-ATR*TL)		EMRT	0.704	
exp(-ATR*L)		EMRL	0.626	
Rate of tax benefit	3.30	BN	0.057	
Remaining tax life		RTL	5.00	years
Tax Benefit Rate: (1-%NC)*BN		BEN	0.028	
Discount factor: @exp(-ATR*(L-(TL-RTL)))		DIS	0.66	
Loss of tax benefit on portion of existing capital with remaining tax life		LEC1	0.123	
Loss of tax benefit on discounted existing capital expenditure in the future		LEC2	0.095	
LEVELIZED CC			GROSS CC	TAX EFF
Initial Cost			1.000	
Tax Benefit of Straight-Line Depreciation				0.287
Savings from not replacing existing Capital later			-0.332	
Loss of Tax Benefit from existing Capital				-0.218
Present Value of CC:			0.668	0.069
Adjusted for Capital Lead Time			0.732	0.075
Levelized Tax Benefit: 1-X dep. of existing Cap.				0.005
LEVELIZED CC FACTOR		CCLF	0.115	0.016
AVERAGE ASSET FACTOR				
Asset Factor for Any New Cap. or Asset		AFB	0.578	
Average Asset Factor for Add-on Capital		AAF	0.289	
INPUT				
NEW CAP. COST: 1987-96 (\$000)	CC.B0	0.00		
1996 CHANGE	CC.N	0.00		
COEFFICIENTS OF VARIATION	CCLCV	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.13 Cooktops Version of LBL-MIM

The Long-Run Model Module

1990 CASE		A.F	A.Q	A:R	A	
Assets -->		0.027	0.747	0.774	77	
Costs except taxes		TC.F	TC.Q	TC:R	TC	
and equity -->		0.133	0.799	0.931	93	
		EC.F	EC.Q	EC:R	EC	
Economic costs -->		0.089	0.570	0.999	100	
	Economic Income			EI:R	0.0011	
	Markup (mu - 1)			mul	0.1586	
	Price Leader's elasticity of demand:				-7.3	
BASE 1996		A.BF	A.BQ		A.B	
Assets		2.69	73.92		77.11	
		TC.BF	TC.BQ		TC.B	
Costs except taxes		13.25	79.07		93	
		EC.BF	EC.BQ		EC.B	
Economic costs		8.90	56.40		100	
NEW 1996		A.NF	A.NQ		A.N	
Assets		2.69	73.92		77.98	
		TC.NF	TC.NQ		TC.N	
Costs except taxes		13.25	79.27		94	
		EC.NF	EC.NQ		EC.N	
Economic costs		8.90	56.54		100	
Assets	-----1990-----		---BASE 1996---		----NEW 1996----	
Shipments	"Q	1.01	Q.B	1.01	Q.N	1.02
Price	"P	\$99.01	P.B	\$99.01	P.N	\$99.01
Revenue	"R	99.68	R.B	99.68	R.N	100.85
Unit Var. Cost	"UVC	\$78.43	UVC.B	\$78.43	UVC.N	\$78.64
V. Cost Goods Sold	VCGS	78.96	VCGS.B	78.96	VCGS.N	80.10
1X tax benefit			X1T.B	0.00	X1T.N	0.00
Pre-tax cost	PTC	92.85	PTC.B	92.85	PTC.N	94.00
Taxes	TAX	2.32	TAX.B	2.32	TAX.N	2.33
Net Income	NI	4.51	NI.B	4.51	NI.N	4.52
Economic Income	EI	0.11	EI.B	0.11	EI.N	0.08
Equity	EQ	61.69	EQ.B	61.69	EQ.N	62.38
Retrn on Equity	"ROE	7.31%	ROE.B	7.31%	ROE.N	7.25%
ACCOUNTING PAGE CALCULATIONS						
	-----1990-----		---BASE 1996---		----NEW 1996----	
Interest not 1X	IC	0.35	IC.B	0.20	IC.N	0.20
Pre-intrst cst	PIC	92.50	PIC.B	92.66	PIC.N	93.80
1X depreciation			X1D.B	0.00	X1D.N	0.00
1X interest			X1I.B	0.00	X1I.N	0.00
1X equity cost			X1E.B	0.00	X1E.N	0.00

Table C.14 Cooktops Version of LBL-MIM

The Short-Run Model Module

Short-Run "Supply Elasticity of Price":				SRQE.0	0.157
$(Q/P) \cdot dP/dQ$					
Standard Error of SRQE				SRQE.SD	0.120
Random Value selected for this run:				"SRQE	0.037
R.S	100.88		"P.N	\$99.01	
UVC.S	\$78.64		"Q.N		1.02
VCGS.S	80.09				
TC.S	93.98			ap	bp
TAX.S	2.34	P=a+bQ		95.32	3.67
PTC.S	93.98		1.00	cq	dq
NLS	4.55	Q=c+dP		1.36	0.00
A.S	77.98				
EQ.S	62.38		P.S	99.06	
ROE.S	7.29%		Q.S		1.02
Check P				\$99.06	
Check Q					1.0182

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.15 Cooktops Version of LBL-MIM

The Charts Module

CHARTS OF SENSITIVITY AND PROFIT FOR COOKTOPS

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

Scenario = Primary

Control Variables		Possible Standards Levels					
Name	Value	Changed	1	2	3	4	5
IPE	-0.330	-0.759	0.03%	-0.01%	-0.09%	-0.49%	-1.32%
RD	200.00%	459.84%	0.09%	0.13%	0.16%	0.20%	0.34%
ECC	0.090	0.099	0.00%	0.00%	0.00%	-0.03%	-0.04%
EP	0.005	0.015	-0.02%	-0.01%	0.00%	-0.08%	-0.01%
FCA	0.100	0.160	-0.02%	0.01%	0.08%	0.35%	0.93%
FIX	0.200	0.348	-0.06%	-0.06%	-0.06%	-0.60%	-0.68%
CC.N	5.460	6.656	-0.01%	-0.01%	-0.01%	-0.15%	-0.22%
dVC.N	3.912	5.246	0.04%	0.07%	0.12%	0.18%	0.45%
ro.N	0.000	0.300	0.02%	-0.01%	-0.08%	-0.35%	-0.95%
SRPR	0.157	0.594	0.00	0.00	0.00	0.00	0.00

Change in Long-Run ROE from 1996 NAECA Base Case by Engineering and Standards Levels

Scenario = Primary

Level	Engin	Standrds
1	-0.03%	-0.03%
2	-0.43%	-0.49%
3	0.30%	0.19%
4	0.44%	0.90%
5	0.89%	1.35%
6		

Table C.16 Ovens Version of LBL-MIM

Control Panel

OVENS CONTROL FACTORS	Scenario: Primary		Standard Level = 1		
	Input Value	Cntrl	Vari- ation	Progrm Value	Name
Price Elasticity	-0.150	0.00	100%	-0.150	IPE
Consumer Discount Rate	37.48%	0.00	100%	37.48%	RD
Equity Cost of Capital	0.068	0.00	10%	0.068	ECC
Economic Profit	0.018	0.00	1%	0.018	EP
L-R Fixed Part of Costs & Assets	0.017	0.00	50%	0.017	FCA
L-R Fixed Part of 1-X Cap. Cost	0.057	0.00	60%	0.057	FIX
One-Time Capital Costs	0.166	0.00	20%	0.166	CCN
Unit Variable Cost Increase	\$2.23	0.00	30%	2.226	dVCN
Elasticity Curve Parameter	0.000	0.00	30%	0.000	roN
Short Run Price Response to Demand	0.157	0.00	76%	0.157	SRPR
SUMMARY	NAECA	NEW	PREVIOUS		
	BASE	L-RUN	CHANGE	CHANGE	S-RUN
Shipments	1.04	1.05	0.15%	0.19%	1.05
Price	\$211.11	\$212.58	0.69%	0.75%	\$212.66
Revenue (in \$M)	220.44	222.31	0.85%	0.94%	222.38
Net Income	11.73	11.71	-0.02	-0.01	11.76
ROE	8.62%	8.60%	-0.03%	-0.10%	8.63%
			Trys =	2.00	

Table C.17 Ovens Version of LBL-MIM

The Monte Carlo Module

MONTE CARLO DETERMINATION OF STANDARD ERRORS OF ESTIMATES.

				Secnds/iteration =	1.63	time
				Iterations to go =	0.00	nn
OVENS					Sample Size =	41.00
	%dQ	%dP	%dR	%dNI	dROE.N	dROE.S
Value	0.15%	0.69%	0.85%	-1.62%	-0.03%	0.01%
Means	0.11%	1.47%	1.55%	-1.28%	-0.02%	0.04%
Std. Dev	0.61%	4.81%	4.09%	4.84%	0.05%	0.17%
	0.00	0.01	0.01	0.01	0.00	0.00
	0.00	0.00	0.01	0.00	0.00	0.00
	0.00	0.00	0.00	-0.09	0.00	0.00
	0.00	0.01	0.01	0.07	0.00	0.00
	0.00	0.01	0.01	0.02	0.00	0.00
	0.00	0.01	0.01	0.00	0.00	0.00
	0.00	0.00	0.01	0.00	0.00	0.00
	0.00	0.01	0.01	-0.08	0.00	0.00
	0.00	0.01	0.01	0.02	0.00	0.00
	0.00	0.01	0.01	-0.01	0.00	0.00
	0.00	0.01	0.01	-0.01	0.00	0.00
	0.00	0.01	0.01	0.00	0.00	0.00
	0.00	0.00	0.01	-0.05	0.00	0.00
	0.00	0.00	0.01	-0.04	0.00	0.00
	0.00	0.01	0.01	-0.04	0.00	0.00
	0.00	0.00	0.01	-0.01	0.00	0.00
	0.00	0.01	0.01	0.00	0.00	0.00
	0.00	0.01	0.01	0.00	0.00	0.00
	0.01	0.01	0.02	0.05	0.00	0.01
	0.00	0.01	0.01	-0.02	0.00	0.00
	0.00	0.01	0.01	0.00	0.00	0.00
	0.01	0.01	0.01	0.01	0.00	0.00
	0.01	0.01	0.02	0.15	0.00	0.00
	0.00	0.01	0.01	-0.08	0.00	0.00
	0.00	0.01	0.01	0.01	0.00	0.00
	0.00	0.01	0.01	-0.04	0.00	0.00
	0.00	0.01	0.01	0.03	0.00	0.00
	0.00	0.01	0.01	-0.03	0.00	0.00
	0.00	0.00	0.00	-0.01	0.00	0.00
	0.00	0.00	0.01	-0.10	0.00	0.00
	0.00	0.00	0.00	-0.06	0.00	0.00
	0.01	0.01	0.01	0.03	0.00	0.00
	0.01	0.00	0.01	-0.06	0.00	0.00
	0.00	0.01	0.01	-0.01	0.00	0.00

Table C.18 Ovens Version of LBL-MIM***The Accounting Module***

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

	1990	BASE '96	NEW '96	CHANGE
Revenue	219.49	220.44	222.31	0.8%
Expenses				
Cost of Goods Sold	146.19	147.09	148.89	1.2%
Selling & G & A	43.11	43.47	43.55	0.2%
Engineering	3.55	3.58	3.58	0.2%
Depreciation	8.10	8.10	8.10	NA
1-X Depreciation	0.00	0.01	0.02	NA
Total Expenses	200.95	202.24	204.13	0.9%
Earnings Before Interest & Taxes	18.55	18.20	18.17	-0.1%
Interest	0.77	0.43	0.43	-0.5%
Earnings Before Taxes	17.78	17.77	17.74	-0.1%
Taxes	6.05	6.04	6.04	-0.1%
Net Income	11.74	11.72	11.71	-0.2%
Gross Margin	33.40%	33.27%	33.03%	-0.74%
Return on Sales	5.35%	5.32%	5.27%	-1.0%
Total Assets	169.79	169.97	170.26	0.2%
Return on Assets (w/intrst taxed)	7.21%	7.06%	7.04%	0.0
Equity	135.83	135.98	136.21	0.2%
Return on Equity	8.64%	8.62%	8.59%	0.0
ECONOMIC ANALYSIS				
	1990	BASE '96	NEW '96	CHANGE
INCOME				
Shipments	1.04	1.04	1.05	0.2%
Price	\$210.42	\$211.11	\$212.58	0.7%
Revenue	219.49	220.44	222.31	0.8%
EXPENSE (W/ INTEREST)				
Fixed Costs	3.65	3.65	3.65	-9.2%
Variable Cost (w/ Q)	198.06	199.02	3.82	-11.5%
Total Expenses	0.00	201.71	202.67	-10.9%
ASSETS				
Cash	27.87	27.90	27.94	-10.9%
Inventories	97.39	97.49	97.64	0.2%
Depreciable	-830.60	-797.52	-703.37	-11.8%
Total Assets	169.79	169.97	170.26	0.2%

Table C.19 Ovens Version of LBL-MIM

The Engineering Inputs Module

Increment in Additional UVC by Level and Class												
Baseline	0	1	2	3	4	5	6	7	8	9	10	11
E-CONV	133.01	0.00	0.94	1.57	1.25	3.76	7.48	2.10	3.18	56.88	11.42	2.88
E-SELF	168.49	0.00	1.42	8.64	3.76	2.19	56.88	11.54	3.10	1.42	8.64	3.76
G-CONV	140.56	0.00	5.83	1.57	0.89	1.27	3.76	8.45	2.11	3.54	25.91	2.90
G-SELF	200.43	0.00	0.86	1.42	3.76	2.19	10.02	3.10	36.94	0.86	1.42	3.76
VCSE Additional UVC. (Above Level 0 cost). Lots of Branches												
CLS	0	1	2	3	4	5	6	7	8	9	10	11
0	0	0	1	3	4	8	15	17	20	77	89	91
1	0	0	1	10	14	16	73	84	88	1	10	14
2	0	0	6	7	8	10	13	22	24	27	53	56
3	0	0	1	2	6	8	18	21	58	1	2	6
Electricity in Kw Hrs /Yr (ADJ)												
	0	1	2	3	4	5	6	7	8	9	10	11
E-CONV	327.18	315.89	298.70	286.98	278.27	256.77	223.79	217.46	211.32	161.20	157.56	157.35
E-SELF	346.71	336.88	328.67	287.27	273.22	266.79	212.68	209.37	209.18	337.83	293.46	278.55
G-CONV	0.00	0.00	47.78	47.78	47.78	47.78	47.78	51.86	51.86	51.86	51.86	51.86
G-SELF	80.30	80.30	80.30	80.30	80.30	80.30	84.48	84.48	84.48	80.30	80.30	80.30
KBTU Natural Gas Use in KBTU/Yr												
	0	1	2	3	4	5	6	7	8	9	10	11
G-CONV	3580	3499	1887	1697	1588	1473	1218	1024	999	967	900	896
G-SELF	1882	1815	1709	1616	1405	1365	1182	1177	1132	1768	1668	1443
Annual Operating Costs \$/Yr												
	0	1	2	3	4	5	6	7	8	9	10	11
E-CONV	26.9	26.0	24.6	23.6	22.9	21.1	18.4	17.9	17.4	13.3	13.0	12.9
E-SELF	28.5	27.7	27.0	23.6	22.5	21.9	17.5	17.2	17.2	27.8	24.1	22.9
G-CONV	20.4	19.9	14.7	13.6	13.0	12.3	10.9	10.1	9.9	9.8	9.4	9.4
G-SELF	17.3	16.9	16.3	15.8	14.6	14.4	13.7	13.6	13.4	16.7	16.1	14.8
Capital cost / unit / 7												
	0	1	2	3	4	5	6	7	8	9	10	11
E-CONV	13.2	0.0	0.2	0.1	0.2	0.5	0.7	0.3	0.0	5.6	0.3	0.7
E-SELF	16.7	0.0	0.4	0.9	0.5	0.7	5.6	0.7	1.3	0.4	0.9	0.5
G-CONV	14.2	0.0	0.1	0.1	0.2	0.3	0.5	0.8	0.4	0.0	2.3	0.7
G-SELF	19.8	0.0	0.3	0.4	0.5	0.7	1.0	1.3	9.0	0.3	0.4	0.5

Table C.19 Oven Version of LBL-MIM

The Engineering Inputs Module (Continued)

CC.E	Additional CC./7 (Above Level 0 cost): Lots of Branches												
CLS	0	1	2	3	4	5	6	7	8	9	10	11	
0	0.0	0.0	0.2	0.2	0.4	0.9	1.7	2.0	2.0	7.7	8.0	8.7	
1	0.0	0.0	0.4	1.3	1.7	2.4	8.1	8.7	10.0	0.4	1.3	1.7	
2	0.0	0.0	0.1	0.1	0.3	0.6	1.1	1.9	2.3	2.3	4.7	5.4	
3	0.0	0.0	0.3	0.7	1.2	1.8	2.8	4.1	13.1	0.3	0.7	1.2	
Additional CC *7: Lots of Branches													
	0	1	2	3	4	5	6	7	8	9	10	11	
E-CONV	0	0.0	0.3	0.4	0.8	1.7	3.2	3.8	3.9	14.5	15.1	16.4	
E-SELF	0	0.0	1.0	3.0	4.2	5.8	19.1	20.7	23.7	1.0	3.0	4.2	
G-CONV	0	0.0	0.2	0.3	0.8	1.4	2.5	4.5	5.3	5.4	10.9	12.5	
G-SELF	0	0.0	0.2	0.5	0.8	1.3	2.0	3.0	9.5	0.2	0.5	0.8	
CC.E.E	0	0	2	4	7	10	27	32	42	21	29	34	

Table C.20 Ovens Version of LBL-MIM

The Standards Level Module

Levl'n prev	LEV.B	lev.N	Eng:	0 ...	11	"Emax
-1	0	1	REM:	-1 ...	5	"Smax
1	1	1		1 ==> Stndrds	0 ==> Eng.	
SIE	SIE.B	SIE.N	Esc = QUIT			

VCS.R	Additional UVC by Level and Class. (Above Base cost.)						
LEVEL -->	-1=1990	0=1996	1	2	3	4	5
E-CONV	0.00	0.00	3.77	7.53	17.10	17.10	91.46
E-SELF	0.00	0.00	0.00	1.42	10.06	16.01	87.52
G-CONV	3.60	5.88	7.54	13.32	27.41	27.41	56.23
G-SELF	0.00	0.00	0.00	0.86	2.28	8.23	58.29

KWS.R	Kw Hrs /Yr						
LEVEL -->	-1=1990	0=1996	1	2	3	4	5
E-CONV	26	26	23	21	18	18	13
E-SELF	28	28	28	27	24	22	17
G-CONV	17	15	14	11	10	10	9
G-SELF	17	17	17	16	16	14	13

CC.R							
LEVEL -->	-1=1990	0=1996	1	2	3	4	5
E-CONV	0.00	0.00	0.44	0.92	2.01	2.01	8.66
E-SELF	0.00	0.00	0.00	0.41	1.26	2.43	9.99
G-CONV	0.06	0.26	0.29	1.09	2.35	2.35	5.42
G-SELF	0.00	0.00	0.00	0.26	0.67	1.84	13.14

CCEB.R							
LEVEL -->	-1=1990	0=1996	1	2	3	4	5
Cumltv CC	0	0	5	5	5	61	71
	0	0	0	1	2	2	9

	1990	1996	NEW96	Weighted	Base Case	New Stds
	CPC87	CPCB	CPCN	Op Cost	Weighted	Weighted
					d P	d P
E-CONV	0	0	0.43	6.73	0	0.97
E-SELF	0	0	0	9.00	0	0
G-CONV	0.06	0.25	0.28	5.33	0.72	1.24
G-SELF	0	0	0	1.66	0	0
Wgt Fuel Cost: F				22.74	0.72	2.22
					dVC.B0	dVC.N0
---OUTPUT---						
	CC.87	CCB	CCN	CC.B0	CC.N0	dVC.B.CV
	0.015	0.06	0.18	0.04	0.16	25.00%

Table C.21 Ovens Version of LBL-MIM

The Costs, Sales, and Revenue Module

						bb	136
						aa	149
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 (1990)							
	Indst	Relatv	----- Firm -----				
	Ship.	Ship.	Ship.	Price	Rev.		Weighted
		Q%	Q.1	P.1/Range	R.1	m.1	UVC.1
E-CONV	1.35	0.26	0.27	182.22	49.30	1.31	139.05
E-SELF	1.70	0.33	0.34	230.83	78.30	1.64	140.99
G-CONV	1.65	0.32	0.33	192.57	63.65	1.38	139.54
G-SELF	0.51	0.10	0.10	274.59	28.25	1.93	142.17
TOTAL S	5.22	20.00%	1.04	\$210	219.49	1.50	20.00%
	"TS.0	"Q.CV	Q.0	P.0	R		"P.CV
BASE CASE (1996)							
	Rule-of-	Rule-of-			Op Cost	Weightd	
	Thb d P	Thb Price		Pi.B	Ratio	OpCst-R	Qi.B
E-CONV	0.00	49.35	0	\$182	1.00	0.26	0.2708
E-SELF	0.00	78.37	0	\$231	1.00	0.33	0.3395
G-CONV	3.42	64.84	4	\$195	0.89	0.28	0.3309
G-SELF	0.00	28.28	0	\$275	1.00	0.10	0.1030
TOTALS	0.11	220.85	4	211.1	220.44	-0.03	1.0442
	Alpha.B	Sum P (2)	Sum (3)	"P.B	Sum(Ri)	OC%.B0	"Q.B
check=R.B							
NEW STANDARDS CASE (1996)							
	Rule-of-	Rule-of-			% Chng	Weightd	
	Thb d P	Thb Price		Pi.N	Op Cost	OpCst-R	Qi.N
E-CONV	5.48	50.91	8	\$185.9	0.88	0.23	0.2712
E-SELF	0.00	78.49	0	\$230.8	1.00	0.33	0.3400
G-CONV	5.73	65.71	11	\$196.4	0.80	0.25	0.3314
G-SELF	0.00	28.32	0	\$274.6	1.00	0.10	0.1032
TOTAL	0.06	223.44	19	212.6	222.31	-0.09	1.0458
	Alpha.N	Sum P (2)	Sum (3)	"P.N	Sum(Ri)	OC%.N0	"Q.N
check=R.N							

Table C.22 Ovens Version of LBL-MIM

The Financial Module

INPUT	NAME	VALUE	NAME	C.V. or Control Factor
RATES of COST				
After Tax Equity Cost of Capital	ECC.0	0.07	ECC.CV	10%
Interest Rate on Debt	I.0	2.50%	I.CV	100%
Interest Lost on Cash	ICash.0	0.01	ICASH.CV	100%
Rate of Depreciation	Dep.0	0.18		
Tax Rate	T.0	34.00%	T.CV	20%
ASSETS and COSTS as a PERCENT of REVENUE				
Cash	C:R.0	13%	C:R.CV	100.00%
Inventory & Receivables	IR:R.0	44%	IR:R.CV	27.19%
Depreciable Assets	DA:R.0	20%	DA:R.CV	36.89%
G & A	G&A.0	15%	G&A.CV	40.00%
Engineering	Eng	1.20%		
FIXED AND VARIABLE COST SPLIT				
Fixed Part of All Costs & Depr Assets	FDA.0	1.66%	FCA.CV	50.00%
Fixed Part of 1-X Capital Cost	FIX.0	5.73%	FIX.CV	60.00%
OTHER				
Economic Profit	EP.0	1.84%	EP.CV	1.00%
Debt to Equity ratio	DER.0	25.00%	DER.CV	43.36%
Markup on typical model	"mid	38.00%		
Ratio of highest to lowest markup	"ratio	300.00%		
OUTPUT				
Depreciation	DRR	3.7%		
G&A to Overhead Ratio	G:O	92.4%		
Engineering to Overhead Ratio	E:O	7.6%		
Debt Ratio	DR	20.0%		
Equity Ratio	ER	80.0%		
Pre-Tax Equity Cost of Capital*	PECC	10.3%		
Weighted Average Cost of Capital	WACC	8.7%		
After Tax WACC	ATWACC	5.8%		
Return on Equity	ROE	0.086		
Real - ROE Input	ROE.0	8.64%		

All interest rates and costs of capital are "real".

*When Pre-Tax ECC is used, all costs are counted tax-exempt.

Table C.23 Ovens Version of LBL-MIM

The One-Time Cost Amortization Module

INPUTS

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	5.61%	
Weighted CC Lead-Time Factors	0.00	0.29	0.54 0.26
Cumulative CC Lead-Time Factors	LTC.0	1.092	
exp(-ATR*TL)	EMRT	0.714	
exp(-ATR*L)	EMRL	0.638	
Rate of tax benefit	3.30	BN	0.057
Remaining tax life	RTL	5.00 years	
Tax Benefit Rate: (1-%NC)*BN	BEN	0.028	
Discount factor: @exp(-ATR*(L-(TL-RTL)))	DIS	0.68	
Loss of tax benefit on portion of existing capital with remaining tax life	LEC1	0.124	
Loss of tax benefit on discounted existing capital expenditure in the future	LEC2	0.097	
LEVELIZED CC		GROSS CC	TAX EFF
Initial Cost		1.000	
Tax Benefit of Straight-Line Depreciation			0.289
Savings from not replacing existing Capital later		-0.338	
Loss of Tax Benefit from existing Capital			-0.221
Present Value of CC:		0.662	0.068
Adjusted for Capital Lead Time		0.723	0.074
Levelized Tax Benefit: 1-X dep. of existing Cap.			0.004
LEVELIZED CC FACTOR	CCLF	0.112	0.016
AVERAGE ASSET FACTOR			
Asset Factor for Any New Cap. or Asset	AFB	0.574	
Average Asset Factor for Add-on Capital	AAF	0.287	

INPUT

NEW CAP. COST: 1987-96 (\$000)	CC.B0	0.05
1996 CHANGE	CC.N	0.17
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	0.01	LCC.N	0.02
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	0.02
Levelized 1-X Assets	LA.B	0.01	LA.N	0.05

Table C.24 Ovens Version of LBL-MIM

The Long-Run Model Module

1990 CASE		A.F	A.Q	A.R	A
Assets -->		0.003	0.770	0.774	170
Costs except taxes and equity -->		TC.F	TC.Q	TC.R	TC
		0.017	0.902	0.919	202
		EC.F	EC.Q	EC.R	EC
Economic costs -->		0.011	0.637	0.989	217
	Economic Income			EI.R	0.0114
	Markup ($\mu - 1$)			μ 1	0.0354
	Price Leader's elasticity of demand:				-29.3
BASE 1996		A.BF	A.BQ		A.B
Assets		0.74	162.06		169.97
		TC.BF	TC.BQ		TC.B
Costs except taxes		3.65	190.60		203
		EC.BF	EC.BQ		EC.B
Economic costs		2.45	134.61		218
NEW 1996		A.NF	A.NQ		A.N
Assets		0.74	162.06		170.26
		TC.NF	TC.NQ		TC.N
Costs except taxes		3.65	192.10		205
		EC.NF	EC.NQ		EC.N
Economic costs		2.45	135.62		219
Assets	-----1990-----	---BASE 1996---	---NEW 1996---		
Shipments	"Q 1.04	Q.B 1.04	Q.N	1.05	
Price	"P \$210.42	P.B \$211.11	P.N	\$212.58	
Revenue	"R 219.49	R.B 220.44	R.N	222.31	
Unit Var. Cost	"UVC \$140.14	UVC.B \$140.87	UVC.N	\$142.37	
V. Cost Goods Sold	VCGS 146.19	VCGS.B 147.09	VCGS.N	148.89	
1X tax benefit		X1T.B 0.00	X1T.N	0.00	
Pre-tax cost	PTC 201.71	PTC.B 202.67	PTC.N	204.56	
Taxes	TAX 6.05	TAX.B 6.04	TAX.N	6.04	
Net Income	NI 11.74	NLB 11.73	NLN	11.71	
Economic Income	EI 2.50	ELB 2.48	ELN	2.45	
Equity	EQ 135.83	EQ.B 135.98	EQ.N	136.21	
Retm on Equity	"ROE 8.64%	ROE.B 8.62%	ROE.N	8.60%	
ACCOUNTING PAGE CALCULATIONS					
	-----1990-----	---BASE 1996---	---NEW 1996---		
Interest not 1X	IC 0.77	IC.B 0.43	IC.N	0.43	
Pre-intrat cst	PIC 200.95	PIC.B 202.24	PIC.N	204.13	
1X depreciation		X1D.B 0.01	X1D.N	0.02	
1X interest		X1LB 0.00	X1LN	0.00	
1X equity cost		X1E.B 0.00	X1E.N	0.00	

Table C.25 Ovens Version of LBL-MIM

The Short-Run Model Module

<i>Short-Run "Supply Elasticity of Price":</i>				<i>SRQE.D</i>	<i>0.157</i>
<i>(Q/P)*dP/dQ</i>					
<i>Standard Error of SRQE</i>				<i>SRQE.SD</i>	<i>0.120</i>
<i>Random Value selected for this run:</i>				<i>"SRQE</i>	<i>0.157</i>
R.S	222.38		"P.N	\$212.58	
UVC.S	\$142.37		"Q.N		1.05
VCGS.S	148.88				
TC.S	204.53			ap	bp
TAX.S	6.07	P=a+bQ		179.20	31.99
PTC.S	204.55		1.00	cq	dq
NLS	11.76	Q=c+dP		1.20	0.00
A.S	170.26				
EQ.S	136.21		P.S	212.66	
ROES	8.63%		Q.S		1.05
		Check P		\$212.62	
		Check Q			1.0457

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 Version of LBL-MIM

The Charts Module

CHARTS OF SENSITIVITY AND PROFIT FOR OVENS

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

Scenario = Primary

Control Variables			Possible Standards Levels				
Name	Value	Changed	1	2	3	4	5
IPE	-0.150	-0.345	0.00%	0.01%	0.00%	0.00%	-0.12%
RD	37.48%	86.17%	0.03%	0.06%	0.12%	0.13%	0.29%
ECC	0.068	0.075	0.00%	0.00%	0.00%	0.00%	-0.01%
EP	0.018	0.028	-0.01%	-0.01%	0.00%	0.00%	0.18%
FCA	0.017	0.027	-0.01%	-0.01%	0.00%	0.01%	0.18%
FIX	0.057	0.100	0.00%	-0.01%	-0.01%	-0.02%	-0.09%
CC.N	0.166	0.203	0.00%	0.00%	0.00%	-0.01%	-0.03%
dVC.N	2.226	2.985	0.01%	0.02%	0.07%	0.08%	0.31%
ro.N	0.000	0.300	0.01%	0.02%	0.00%	-0.01%	-0.27%
SRPR	0.157	0.594	0.00	0.00	0.00	0.00	0.00

Change in Long-Run ROE from 1996 NAECA Base Case by Engineering and Standards Levels

Scenario= Primary

Level	Engin	Stndrds
1	-0.02%	-0.03%
2	-0.12%	-0.05%
3	-0.15%	-0.01%
4	-0.32%	-0.01%
5	-0.20%	0.48%

Table C.27 Microwave Ovens Version of LBL-MIM

Control Panel

Scenario: Primary			Standard Level = 1		
MICROWAVE OVENS		Input	Vari-	Progrm	
CONTROL FACTORS		Value	ation	Value	Name
Price Elasticity		-0.600	100%	-0.600	IPE
Consumer Discount Rate		250.00%	100%	250.00%	RD
Equity Cost of Capital		0.068	10%	0.068	ECC
Economic Profit		0.018	1%	0.018	EP
L-R Fixed Part of Costs & Assets		0.040	50%	0.040	FCA
L-R Fixed Part of 1-X Cap. Cost		0.042	60%	0.042	F1X
One-Time Capital Costs		0.000	20%	0.000	CC.N
Unit Variable Cost Increase		\$5.00	30%	5.000	dVC.N
Elasticity Curve Parameter		0.000	30%	0.000	ro.N
Short Run Price Response to Demand		0.157	76%	0.157	SRPR
	NAECA	NEW		PRVIOUS	NEW
SUMMARY	BASE	L-RUN	CHANGE	CHANGE	S-RUN
Shipments	0.77	0.79	2.39%	1.97%	0.79
Price	\$151.20	\$156.00	3.18%	5.14%	\$156.53
Revenue (in \$M)	116.48	123.05	5.64%	7.21%	123.21
Net Income	4.92	5.01	0.09	0.10	5.27
ROE	8.64%	8.59%	-0.05%	-0.05%	9.04%
			Trys =	2.00	

Table C.28 Microwave Ovens Version of LBL-MIM

The Monte Carlo Module

MONTE CARLO DETERMINATION OF STANDARD ERRORS OF ESTIMATES.

				Secnds/iteration =	1.75	time
				Iterations to go =	0.00	nn
MICROWAVE OVENS				Sample Size =	400.00	
	%dQ	%dP	%dR	dNI	dROE.N	dROE.S
Value	2.39%	3.18%	5.64%	8.82%	-0.05%	0.40%
Means	-6.62%	25.73%	17.08%	-20.55%	0.00%	-1.33%
Std. Dev	20.98%	7.63%	26.43%	192.34%	1.62%	9.61%
History	-0.05	0.21	0.15	-0.25	0.00	-0.01
...	-0.04	0.20	0.16	0.15	0.01	-0.02
Range	-0.19	0.21	-0.02	-0.92	0.00	-0.07
Name	0.03	0.15	0.19	-0.20	-0.01	-0.01
Is	-0.06	0.33	0.25	0.03	0.00	-0.01
Carlo	-0.16	0.21	0.02	-0.86	0.00	-0.02
	-0.08	0.37	0.26	-0.47	0.00	-0.01
	-0.08	0.38	0.27	0.71	0.02	0.02
	0.03	0.18	0.22	0.28	0.00	0.05
	-0.46	0.32	-0.29	-3.33	-0.04	0.05
	-0.31	0.29	-0.10	-2.99	-0.03	-0.05
	-0.06	0.24	0.17	0.75	0.02	0.01
	0.14	0.20	0.37	0.70	0.00	0.00
	-0.13	0.30	0.13	-0.48	0.00	-0.01
	-0.27	0.32	-0.04	-1.15	0.00	-0.22
	-0.02	0.18	0.15	0.06	0.00	0.00
	-0.12	0.32	0.17	-0.82	-0.01	-0.03
	-0.04	0.34	0.28	-0.05	0.00	0.00
	-0.13	0.31	0.15	-0.64	0.00	-0.08
	-0.06	0.27	0.19	0.01	0.00	0.00
	-0.14	0.22	0.04	-0.91	-0.01	-0.05
	-0.10	0.28	0.16	-0.30	0.00	0.00
	-0.30	0.25	-0.12	-1.83	-0.01	-0.02
	0.14	0.16	0.33	1.01	0.01	0.02

Table C.29 Microwave Ovens Version of LBL-MIM

The Accounting Module

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

	1990	BASE '96	NEW '96	CHANGE
Revenue	116.48	116.48	123.05	5.6%
Expenses				
Cost of Goods Sold	83.20	83.20	89.13	7.1%
Selling & G & A	19.22	19.34	19.80	2.4%
Engineering	1.96	1.97	2.02	2.4%
Depreciation	4.32	4.32	4.32	NA
1-X Depreciation	0.00	0.00	0.00	NA
Total Expenses	108.70	108.83	115.27	5.9%
Earnings Before Interest & Taxes	7.78	7.65	7.78	1.7%
Interest	0.32	0.19	0.19	-0.4%
Earnings Before Taxes	7.46	7.46	7.59	1.8%
Taxes	2.54	2.54	2.58	1.8%
Net Income	4.92	4.92	5.01	1.8%
Gross Margin	28.57%	28.57%	27.57%	-3.52%
Return on Sales	4.23%	4.23%	4.07%	-3.6%
Total Assets	71.21	71.21	72.89	2.4%
Return on Assets (w/intrst taxed)	7.21%	7.09%	7.05%	0.0
Equity	56.97	56.97	58.31	2.4%
Return on Equity	8.64%	8.64%	8.59%	0.0

ECONOMIC ANALYSIS

	1990	BASE '96	NEW '96	CHANGE
INCOME				
Shipments	0.77	0.77	0.79	2.4%
Price	\$151.20	\$151.20	\$156.00	3.2%
Revenue	116.48	116.48	123.05	5.6%
EXPENSE (W/ INTEREST)				
Fixed Costs	4.66	4.66	4.66	-9.2%
Variable Cost (w/ Q)	104.37	104.37	3.66	-11.5%
Total Expenses	0.00	0.00	0.00	-10.9%
ASSETS				
Cash	10.81	10.81	11.03	-10.8%
Inventories	97.39	97.49	97.64	0.2%
Depreciable	-868.45	-835.45	-740.64	-11.3%
Total Assets	71.21	71.21	72.89	2.4%

Table C.30 Microwave Ovens Version of LBL-MIM

The Engineering Inputs Module

		Increment in Additional UVC by Level and Class					
Baseline		0 0+PowerSupply	1+Pan	2+WaveGuide	3+Magnetron	4+ReflectSurface	
Micro		0.0	5.0	1.1	1.5	13	16
VCS.E	Additional UVC. (Above Level 0 cost.)						
	CLS	0	1	2	3	4	5
	0.00	0.0	5.0	6.1	7.6	20.1	36.5
KWH.PRINT	Kw Hrs /Yr						
KWS.E		0	1	2	3	4	5
Micro		270	239	236	233	230	228
	Capital cost / unit / 7						
		0	1	2	3	4	5
Micro		0.0	0.0	0.0	0.3	0.0	0.0
CC.E	Additional CC. (Above Level 0 cost.)						
	CLS	0	1	2	3	4	5
	0.00	0.0	0.0	0.0	0.3	0.3	0.3
		0	1	2	3	4	5
Micro		0	0	0	2	2	2
CCEE.E		0	0	0	2	2	2

Table C.31 Microwave Ovens Version of LBL-MIM

The Standards Level Module

LevIn prev	LEV.B	lev.N	Eng	0 ...	5	"E _{max}	
-1	0	1	REM:	-1 ...	5	"S _{max}	
1	1	1		1 ==> Stndrds	0 ==> Eng.		
SIE	SIE.B	SIE.N	Esc = QUIT				
VCS.R	Additional UVC by Level and Class. (Above Base cost.)						
LEVEL -->	-1=1987	0=1996	1	2	3	4	5
Color	0	0	5	6.06	7.56	20.06	36.48
KWS.R	Kw Hrs /Yr						
LEVEL -->	-1=1987	0=1996	1	2	3	4	5
Color	270	270	239	236	233	230	228
CC.R							
LEVEL -->	-1=1990	0=1996	1	2	3	4	5
Color	0	0	0	0	0.33	0.33	0.33
CCEER							
LEVEL -->	-1=1990	0=1996	1	2	3	4	5
Cumltv CC	0	0	5	5	5	61	71
	0	0	0	0	2	2	2
	1990	1996	NEW96	1990	1996	NEW96	
	VC87	VCB	VCN	KW87	KWB	KWN	
Color	0	0	5	270	270	239	
	1990	1996	NEW96		Weighted		Weighted
	CPC87	CPCB	CPCN		Op Cost		Fuel Cost
Color	0	0	0		270	F	232.5024
	CC.87	CCB	CCN	---OUTPUT---			
	0	0	0	CC.B0	CC.N0		
	0	0	0	0	0		

Table C.32 Microwave Ovens Version of LBL-MIM

The Costs, Sales, and Revenue Module

							bb	151.20
							aa	0
Ratio of highest to lowest markup:				ratio.0	1.00		ratio.cv	1.00
Typical markup over UVC				mid.0	0.38		mid.cv	1.00
Size of firm as % of industry				size.0	0.08			
CALIBRATION CASE (1990)								
	Indst	Relatv	----- Firm -----					
	Ship.	Ship.	Ship.	Price	Rev.			Weighted
		Q%	Q.1	P.1	R.1	m.1	UVC.1	"UVC
Microwaves	9.63	1.00	0.77	151.20	116.48	1.40	108.00	108.00
TOTAL S	9.63	20.00%	0.77	\$151	116.48	1.40	20.00%	\$108.00
	"TS.0	"Q.CV	Q.0	P.0	R		"P.CV	UVC
BASE CASE (1996)								
	Change	Weighted	Wghtd		Op Cost	Weightd		
	in UVC	C in UVC	d P	Pi.B	Ratio	OpCst-R	Qi.B	Ri.B
	0.00	0.00	0.00	151.20	1.00	1.00	0.77	116.48
TOTALS	0.00	0.00	0.00	\$151	116.48	0.00	0.7704	116.48
	Mark.B	dVC.B	Pdiff.B	"P.B	Sum(Ri)	OC%.B0	"Q.B	"R.B
					check=R.B.			
	dVC.B.CV	25.00%						
NEW STANDARDS CASE (1996)								
	Change	Weighted	Wghtd		% Chng	Weightd		
	in UVC	C in UVC	d P	Pi.N	Op Cost	OpCst-R	Qi.N	Ri.N
	5.00	5.00	7.00	\$156	0.89	0.89	0.7888	123.05
TOTAL	0.69	5.00	7.00	\$156	123.05	-0.11	0.7888	123.05
	Mark.N	dVC.N0	Pdiff.N	"P.N	Sum(Ri)	OC%.N0	"Q.N	"R.N
					check=R.B.			

Table C.33 Microwave Ovens Version of LBL-MIM

The Financial Module

INPUT	NAME	VALUE	NAME	C.V. or Control Factor
RATES of COST				
After Tax Equity Cost of Capital	ECC.0	0.07	ECC.CV	10%
Interest Rate on Debt	I.0	2.50%	I.CV	100%
Interest Lost on Cash	ICash.0	0.01	ICASH.CV	100%
Rate of Depreciation	Dep.0	0.18		
Tax Rate	T.0	34.00%	T.CV	20%
ASSETS and COSTS as a PERCENT of REVENUE				
Cash	C:R.0	9%	C:R.CV	100.00%
Inventory & Receivables	IR:R.0	31%	IR:R.CV	27.19%
Depreciable Assets	DA:R.0	20%	DA:R.CV	36.89%
G & A	G&A.0	12%	G&A.CV	40.00%
Engineering	Eng	1.20%		
FIXED AND VARIABLE COST SPLIT				
Fixed Part of All Costs & Depr Assets	FDA.0	4.00%	FCA.CV	50.00%
Fixed Part of 1-X Capital Cost	F1X.0	4.20%	F1X.CV	60.00%
OTHER				
Economic Profit	EP.0	1.84%	EP.CV	1.00%
Debt to Equity ratio	DER.0	25.00%	DER.CV	43.36%
Markup on typical model	"mid	38.00%		
Ratio of highest to lowest markup	"ratio	100.00%		
OUTPUT				
Depreciation	DRR	3.7%		
G&A to Overhead Ratio	G:O	90.8%		
Engineering to Overhead Ratio	E:O	9.2%		
Debt Ratio	DR	20.0%		
Equity Ratio	ER	80.0%		
Pre-Tax Equity Cost of Capital*	PECC	10.3%		
Weighted Average Cost of Capital	WACC	8.7%		
After Tax WACC	ATWACC	5.8%		
Return on Equity	ROE	0.086		
Real ROE (See MICROMET.WK3)	ROE.0	8.6%		

All interest rates and costs of capital are "real".

*When Pre-Tax ECC is used, all costs are counted tax-exempt.

Table C.34 Microwave Ovens Version of LBL-MIM

The One-Time Cost Amortization Module

INPUTS				
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	5.61%	
Weighted CC Lead-Time Factors	0.00	0.29	0.54	0.26
Cumulative CC Lead-Time Factors		LTC.0	1.092	
$\exp(-ATR \cdot TL)$		EMRT	0.714	
$\exp(-ATR \cdot L)$		EMRL	0.638	
Rate of tax benefit	3.30	BN	0.057	
Remaining tax life		RTL	5.00	years
Tax Benefit Rate: $(1 - \%NC) \cdot BN$		BEN	0.028	
Discount factor: $@\exp(-ATR \cdot (L - (TL - RTL)))$		DIS	0.68	
Loss of tax benefit on portion of existing capital with remaining tax life		LEC1	0.124	
Loss of tax benefit on discounted existing capital expenditure in the future		LEC2	0.097	
LEVELIZED CC			GROSS CC	TAX EFF
Initial Cost			1.000	
Tax Benefit of Straight-Line Depreciation				0.289
Savings from not replacing existing Capital later			-0.338	
Loss of Tax Benefit from existing Capital				-0.221
Present Value of CC:			0.662	0.068
Adjusted for Capital Lead Time			0.723	0.074
Levelized Tax Benefit: 1-X dep. of existing Cap.				0.004
LEVELIZED CC FACTOR		CCLF	0.112	0.016
AVERAGE ASSET FACTOR				
Asset Factor for Any New Cap. or Asset		AFB	0.574	
Average Asset Factor for Add-on Capital		AAF	0.287	
INPUT				
NEW CAP. COST: 1990-96 (\$000)	CC.B0	0.00		
1996 CHANGE	CC.N	0.00		
COEFFICIENTS OF VARIATION	CCLCV	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.35 Microwave Ovens Version of LBL-MIM

The Long-Run Model Module

1990 CASE		A.F	A.Q	A.R	A
Assets -->		0.008	0.603	0.611	71
Costs except taxes		TC.F	TC.Q	TC.R	TC
and equity -->		0.040	0.896	0.936	109
		EC.F	EC.Q	EC.R	EC
Economic costs -->		0.027	0.624	0.991	115
Economic Income				EI.R	0.0090
Markup (mu - 1)				mul	0.0574
Price Leader's elasticity of demand:					-18.4
BASE 1996		A.BF	A.BQ		A.B
Assets		0.95	91.20		71.21
		TC.BF	TC.BQ		TC.B
Costs except taxes		4.66	135.47		109
		EC.BF	EC.BQ		EC.B
Economic costs		3.13	94.37		115
NEW 1996		A.NF	A.NQ		A.N
Assets		0.95	91.20		72.89
		TC.NF	TC.NQ		TC.N
Costs except taxes		4.66	140.47		115
		EC.NF	EC.NQ		EC.N
Economic costs		3.13	97.67		120
Assets	-----1990-----	---BASE 1996---		---NEW 1996---	
Shipments	"Q 0.77	Q.B	0.77	Q.N	0.79
Price	"P \$151.20	P.B	\$151.20	P.N	\$156.00
Revenue	"R 116.48	R.B	116.48	R.N	123.05
Unit Var. Cost	"UVC \$108.00	UVC.B	\$108.00	UVC.N	\$113.00
V. Cost Goods Sold	VCGS 83.20	VCGS.B	83.20	VCGS.N	89.13
1X tax benefit		X1T.B	0.00	X1T.N	0.00
Pre-tax cost	PTC 109.03	PTC.B	109.03	PTC.N	115.46
Taxes	TAX 2.54	TAX.B	2.54	TAX.N	2.58
Net Income	NI 4.92	NI.B	4.92	NI.N	5.01
Economic Income	EI 1.05	EI.B	1.05	EI.N	1.05
Equity	EQ 56.97	EQ.B	56.97	EQ.N	58.31
Retm on Equity	"ROE 8.64%	ROE.B	8.64%	ROE.N	8.59%

Table C.36 Microwave Ovens Version of LBL-MIM

The Short-Run Model Module

Short-Run "Supply Elasticity of Price":		SRQE.0	0.157
$(Q/P) \cdot dP/dQ$			
Standard Error of SRQE		SRQE.SD	0.120
Random Value selected for this run:		"SRQE	0.157
R.S	123.21	"P.N	\$156.00
UVC.S	\$113.00	"Q.N	0.79
VCGS.S	88.94		
TC.S	115.22	ap	bp
TAX.S	2.71	P=a+bQ	131.51 31.79
PTC.S	115.22	0.98	cq dq
NLS	5.27	Q=c+dP	1.29 0.00
A.S	72.89		
EQ.S	58.31	P.S	156.53
ROE.S	9.04%	Q.S	0.79
		Check P	\$156.53
		Check Q	0.7860

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.37 Microwave Ovens Version of LBL-MIM

The Charts Module

CHARTS OF SENSITIVITY AND PROFIT FOR MICROWAVE OVENS

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

Scenario = Primary

Control Variables			Possible Standards Levels				
Name	Value	Changed	1	2	3	4	5
IPE	-0.600	-1.380	0.16%	0.16%	0.14%	-0.21%	-0.77%
RD	250.00%	574.80%	0.05%	0.06%	0.07%	0.18%	0.33%
ECC	0.068	0.075	0.00%	0.00%	0.00%	0.00%	0.00%
EP	0.018	0.028	-0.02%	-0.02%	-0.03%	0.02%	0.09%
FCA	0.040	0.064	0.00%	0.00%	0.00%	0.00%	0.01%
FIX	0.042	0.073	0.00%	0.00%	-0.01%	0.00%	0.00%
CC.N	0.000	0.000	0.00%	0.00%	0.00%	0.00%	-0.01%
dVC.N	5.000	6.706	0.01%	0.02%	0.02%	0.05%	0.09%
ro.N	0.000	0.300	0.10%	0.10%	0.08%	-0.12%	-0.43%
SRPR	0.157	0.594	0.00	0.00	0.00	0.00	0.00

Change in Long-Run ROE from 1996 NAECA Base Case by Engineering and Standards Levels

Scenario = Primary

Level	Engin	Standrds
1	-0.05%	-0.05%
2	-0.05%	-0.05%
3	-0.05%	-0.05%
4	0.03%	0.03%
5	0.14%	0.14%
6		
7		
8		
9		
10		
11		
12		

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