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Vol. 1 of 3

TECHNICAL SUPPORT DOCUMENT: ENERGY EFFICIENCY STANDARDS FOR CONSUMER PRODUCTS:

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

VOLUME 1: METHODOLOGY

Including:

Environmental Assessment (DOE/EA-0819)

Regulatory Impact Analysis

November 1993

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

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CHAPTER 1. EXECUTIVE SUMMARY

The Energy Policy and Conservation Act (P.L. 94-163), as amended, establishes energy conservation standards for 12 of the 13 types of consumer products specifically covered by the Act. The legislation requires the Department of Energy (DOE) to consider new or amended standards for these and other types of products at specified times. DOE is currently considering amending standards for seven types of products: water heaters, direct heating equipment, mobile home furnaces, pool heaters, room air conditioners, kitchen ranges and ovens (including microwave ovens), and fluorescent light ballasts and is considering establishing standards for television sets. This Technical Support Document presents the methodology, data, and results from the analysis of the energy and economic impacts of the proposed standards.

The economic impact analysis is performed in four major areas:

- An *Engineering Analysis*, which establishes technical feasibility and product attributes, including energy performance and costs of alternative design options, which improve appliance efficiency.
- A *Consumer Analysis*, which forecasts appliance sales, efficiencies, energy use, and consumer expenditures.
- A *Manufacturer Analysis*, which provides an estimate of manufacturers' responses to the proposed standards. Their responses are quantified by changes in several financial performance measures for a prototypical firm.
- An *Impact Analysis*, which provides an integrated framework for assessing the costs and benefits of appliance standards. The Impact Analysis includes: (1) a *Life-Cycle Cost Analysis* that evaluates the savings in operating expense relative to an increase in purchase price for individual consumers; (2) a *Utility Analysis* that measures the impacts of the altered energy-consumption patterns on electric utilities; (3) an *Industry Impact Analysis* that shows the financial and competitive impacts on the respective appliance manufacturing industry; and (4) a *Cost-Benefit Analysis* that collects the results of all the analyses into the net benefits and costs from a national perspective.

The Engineering Analysis segregates product types into separate classes to which different energy conservation standards apply. For each appliance class, baseline units are chosen representing relatively low-efficiency units currently being manufactured. The analysis identifies a series of design options to improve energy efficiency and estimates the factory costs to produce them. Design options are added individually or in combination to the baseline unit to evaluate units that might be produced in response to standards. Factory costs are then marked up to

consumer prices, and life-cycle cost curves are constructed for each class. The payback periods associated with each incremental change in efficiency are also calculated.

The Consumer Analysis focuses on national energy savings and economic impacts on consumers up to the year 2030. It forecasts efficiencies and sales of new appliances by class, as well as appliance usage levels in response to changes in projected energy prices and incomes. These results are used to project energy use and consumer expenditures on fuel and equipment. The net present value of the standards is computed by discounting the differences in the time streams of these expenditures in the "with" and "without" new standards cases.

The Manufacturer Impact Analysis estimates the overall impact of new or amended standards on manufacturers. The analysis examines long-run impacts on (1) profitability, (2) growth, and (3) competitiveness. To do this, two measures of impact are tracked for the industry as a whole and for any segments that may exist: (1) return-on-equity (ROE) and (2) net income. ROE provides the primary measure of profitability; gross margin, return-on-assets (ROA), and return-on-sales (ROS) are also reported. The analysis also shows total assets, shipments, average prices, and revenues. Assets and income are the measures of growth (positive or negative).

Two short-run impacts are also analyzed. First, the ability of the industry as a whole and of specific segments of the industry to make the one-time investments required to meet the new standards is examined. Second, if standards result in decreased sales for the particular industry being analyzed, the analysis examines the possibility of price-cutting while the industry is adjusting to a lower sales volume.

The impacts on individual consumers are evaluated by determining the changes in life-cycle cost resulting from the imposition of the proposed standards.

The Utility Analysis focuses on revenue changes, avoided costs, and reductions in peak electric loads. Utility-avoided costs represent the marginal value of lower fuel consumption as well as the marginal value of lower investment in new generating plants. Reduction in peak loads can lead to deferring the construction of new generating capacity. Because fuel costs and the need for additional capacity are region-specific, the Utility Analysis is conducted on a regional basis.

CHAPTER 2. INTRODUCTION

2.1 PURPOSE AND SCOPE

The Energy Policy and Conservation Act (P.L.94-163), as amended by the National Appliance Energy Conservation Act of 1987 (P.L. 100-12) and by the National Appliance Energy Conservation Amendments of 1988 (P.L. 100-357), provides energy conservation standards for 12 of the 13 types of consumer products¹ covered by the Act, and authorizes the Secretary of Energy to prescribe amended or new energy standards for each type (or class) of covered product.

The assessment of the proposed standards for the eight types of products² presented in this document is designed to evaluate their economic impacts according to the criteria in the Act. It includes an engineering analysis of the cost and performance of design options to improve the efficiency of the products; forecasts of the number and average efficiency of products sold, the amount of energy the products will consume, and their prices and operating expenses; a determination of change in investment, revenues, and costs to manufacturers of the products; a calculation of the costs and benefits to consumers, electric utilities, and the nation as a whole; and an assessment of the environmental impacts of the proposed standards.

2.2 STRUCTURE OF THE DOCUMENT

This technical support document consists of nine volumes (one general and one for each product). Volume A, General Methodology, provides a general description of the analytic approach, including the structure of the major models. Volumes B through I are each specific to a product. Each volume contains the data and documentation specific to the analysis of one product, and the results of that analysis. A reader interested in one product will benefit from reading Volume A for general methodology and the specific volume containing analysis results for the product of interest.

¹ The 13 products covered in the legislation are: (1) refrigerators, refrigerator-freezers, and freezers; (2) room air conditioners; (3) central air conditioners and central air-conditioning heat pumps; (4) water heaters; (5) furnaces; (6) dishwashers; (7) clothes washers; (8) clothes dryers; (9) direct heating equipment; (10) kitchen ranges and ovens; (11) pool heaters; (12) television sets; and (13) fluorescent lamp ballasts.

² The 8 types of products analyzed in this rulemaking are: (1) water heaters; (2) direct heating equipment; (3) mobile home furnaces; (4) pool heaters; (5) room air conditioners; (6) kitchen ranges and ovens (including microwave ovens); (7) televisions; and (8) fluorescent lamp ballasts.

Volume A contains five chapters and five appendices:

- Chapter 1 Executive Summary: summarizes major results.
- Chapter 2 Introduction: outlines the structure of the documents.
- Chapter 3 Analytic Approach: summarizes the methodology used in the analysis; discusses the components of the analysis and their interrelationships; describes the models used, their data requirements, and their outputs; and identifies the primary assumptions of the analysis. This chapter also provides an overview of the methodology employed to examine the sensitivity of the results to changes in the key assumptions, parameters, and exogenous forecasts used in the analysis.
- Chapter 4 Industry Profile: discusses appliance saturations, market shares, and industry structure.
- Chapter 5 Development of Base Case Forecasts: discusses population projections, housing starts, commercial floorspace projections, and energy prices.

The appendices in Volume A cover the following topics:

- Appendix A Methodology for uncertainty analysis of maximum technologically feasible energy efficiency.
- Appendix B Overview of forecasting models: structure of the LBL Residential Energy Model (LBL-REM) and the EPRI COMMEND programs. The principal components of the models are discussed and the component interrelationship is explained. In Volumes B through I, Appendix B describes and defines the inputs to the model specific to each respective end use.
- Appendix C Overview of manufacturer impact analysis (LBL-MIM): outlines how an industry profile of the manufacturing firms affected is constructed; describes how the effects on appliance manufacturers of imposing standards by product are quantified; defines the results of the analysis in terms of changes in gross margin, return on sales, return on equity, return on assets, total assets, and labor requirements; and presents the method for conducting a sensitivity analysis of the results.
- Appendix D Maintenance costs are derived for several components common to more than one appliance type.
- Appendix E Electric utility impact modeling.

Environmental Assessment. Quantifies impacts of standards on emissions of carbon dioxide, nitrogen oxides, and sulfur oxides.

Regulatory Impact Analysis.

Volumes B through I each correspond to a particular product. Each volume is organized into eight chapters and three appendices.

Chapter 1	Engineering Analysis: contains detailed energy use and cost information.
Chapter 2	Base Case Forecasts: describes national forecast of energy consumption, efficiency of new units, units installed in households, and annual appliance sales in the absence of new regulations.
Chapter 3	Projected National Impacts of Standards: discusses the choice of standards levels to be analyzed and the projected impacts of each standard level. The chapter summarizes the energy savings by fuel and product; the sales, average efficiencies, purchase costs, and operating costs of new and replacement appliances; the net present benefit of the standards; and the results of the sensitivity analyses.
Chapter 4	Life-Cycle Costs and Payback Periods: describes the effects of standards on individual purchasers and users of appliances. It compares the life-cycle cost of appliances and other measures of consumer impact with and without the proposed standards.
Chapter 5	Impacts of Standards on Manufacturers: describes the analysis methodology, short and long-run impacts, and sensitivity analysis.
Chapter 6	Impact of Standards on Electric Utilities: describes the effects of standards on the electric utility industry, focusing on marginal costs of electricity, generating capacity growth, changes in regional capacity and energy demand, and changes in utility revenues and costs.
Chapter 7	Environmental Effects: describes standards-induced changes in emissions of oxides of carbon, sulfur, and nitrogen from combustion of fossil fuels for electricity generation and in homes.

Appendices A through C contain more detailed information on the models and databases used in the economic analysis.

- Appendix A** **Energy Use and Cost Data:** provides a breakdown of the costs for each design option.
- Appendix B** **Forecasting Model (LBL-REM or EPRI COMMEND):** gives a detailed description of the data used to calculate consumer impacts. The input data stream for the base case runs is shown and changes to the input data for the standards cases are indicated.
- Appendix C** **Manufacturer Impact Analysis:** provides a detailed description of the model to estimate financial impacts of the imposition of standards on the manufacturers of covered products. The appendix shows the structure of the model, the data sources used, and detailed outputs of base case, standards case, and sensitivity analysis runs.

CHAPTER 3. ANALYTIC APPROACH

3.1 INTRODUCTION

The economic impacts of new or amended energy efficiency standards depend largely on the relationship between the cost of a consumer product and its energy efficiency. The cost-efficiency relationships are determined for each product class based on engineering analyses. DOE has segregated product types into classes to which different energy efficiency standards might apply. The product types and the number of classes of each product type are shown in Table 3.1. Within each class, the energy-conserving designs are ordered by cost-effectiveness; then combinations of energy-saving design options are used to generate the relationships that are inputs to the other analyses of the impacts of setting standards at various efficiency levels.

Identification of product classes, baseline units, design options, and maximum technologically feasible efficiencies is based on information gathered from the trade associations, manufacturers, discussions with researchers, a literature survey, and comments on the Advance Notice of Proposed Rulemaking (ANOPR). Energy use data have been obtained from AHAM (Association of Home Appliance Manufacturers), GAMA (Gas Appliance Manufacturers Association), FTC (Federal Trade Commission), manufacturers, and simulation models. Sources of factory cost data include manufacturers, suppliers, and the ANOPR comments. The cost estimates are combined with the efficiency estimates to generate the cost-efficiency relationships.

The relationships between manufacturer costs and efficiency that are presented in this chapter are used throughout the other parts of the analysis. The engineering analysis also includes determination of maintenance and installation costs for each of the design options studied (see Appendix F of this volume and Chapter 1 of Volumes B through I). The manufacturer analysis uses manufacturer costs to produce retail prices. Retail prices, installation costs, and maintenance costs in conjunction with the corresponding efficiencies are used in the forecasting models to forecast sales and efficiencies and to calculate life-cycle costs and payback periods.

Table 3.1 Product Types and Number of Product Classes

Product Type	Number of Classes
Fluorescent Lamp Ballasts	10
Television Sets	2
Water Heaters	4
Pool Heaters	1
Direct Heating Equipment	16
Mobile Home Furnaces	2
Room Air Conditioners	12
Kitchen Ranges and Ovens	8

This chapter briefly describes how the economic analysis of standards was performed. Section 3.2 presents an overview of the analytic methodology and discusses the major components of the analysis: the Engineering Analysis, the Consumer Analysis (national and individual), the Manufacturer and Industrial Analyses, and the Utility Analysis. The emphasis is on how these components fulfill the seven legislative requirements listed in the Introduction. This section discusses the interrelationships among the components that ensure consistency throughout the analysis.

Section 3.3 describes the computerized models used in the analysis. The models predict consumer, manufacturer, and utility responses to future changes in the economy, including the imposition of minimum efficiency standards. Quantitative estimates of the impacts of standards are calculated from the outputs of the models. The models utilized in the analysis are:

- Engineering Cost and Performance Models;
- Consumer Impact Models;
- Manufacturer Impact Models;
- Utility Impact Model.

The function, data sources, assumptions, and validity of the results for each model are discussed in the product-specific volumes (Volumes B through I).

Section 3.4 discusses the sensitivity analysis performed on the economic impacts and focuses on the methods used to determine the parameters that have the largest effects and to determine their range of variation.

3.2 OVERVIEW OF ANALYTIC FRAMEWORK

The impact of appliance efficiency standards is determined by comparing projections of a wide range of economic variables under the existing legislation with the projections under the proposed standards. For each of the eight products analyzed, these projections are first made for a base case (existing legislation) using the analytic models described below. In each product-specific volume, Chapter 2 describes the data and assumptions used to calculate the baseline forecasts. The calculations are then repeated imposing the proposed standards as discussed in Chapter 3. The differences between the projections of the energy consumption and economic variables in the base and standards cases provide quantitative estimates of the impacts of the standards. To evaluate the significance of the differences, a sensitivity analysis is performed on the key parameters and assumptions.

The economic impact analysis is performed in seven major areas:

- An *Engineering Analysis*, which establishes technical feasibility and product attributes including costs of design options to improve appliance efficiency;
- A *Consumer Analysis* at two levels: national aggregate impacts, and impacts on individuals. The *national aggregate impacts* include LBL Residential Energy Model (LBL-REM) forecasts of appliance sales, efficiencies, energy use, and consumer expenditures. The *individual impacts* are analyzed by Life-Cycle Cost (LCC), Payback Periods, and Cost of Conserved Energy (CCE), which evaluate the savings in operating expenses relative to increases in purchase price;
- A *Manufacturer Analysis*, which provides an estimate of manufacturers' response to the proposed standards. Their response is quantified by changes in several measures of financial performance for a firm;
- An *Industry Impact Analysis*, which shows financial and competitive impacts on the appliance industry;
- A *Utility Analysis* that measures the impacts of the altered energy-consumption patterns on electric utilities;
- An *Environmental Effects Analysis*, which estimates changes in emissions of carbon dioxide, sulfur oxides, and nitrogen oxides, because of reduced energy consumption in the home and at the power plant; and
- A *Regulatory Impact Analysis*, which collects the results of all the analyses into the net benefits and costs from a national perspective.

A simplified diagram of the analysis is shown in Figure 3.1. Each type of analysis is performed for the eight types of products. If appliances having the maximum efficiency improvement that is technologically feasible show no significant energy savings in the Engineering Analysis, then the legislation requires that no modified standard be prescribed for that product type. If the appliance efficiency can be increased to produce significant energy savings, then a detailed energy savings, economic, and impact analysis is done. For each of the eight products, the analysis is performed for a base case plus several trial levels of standards. The selection of trial standard levels by class is described in Chapter 3 for each product-specific volume.

Figure 3.1 Analytic Framework for the Appliance Standard Analysis

Figure 3.1 illustrates the interaction among the Engineering, Consumer, and Manufacturer Analyses. The Engineering Analysis establishes appliance designs and related attributes such as efficiency and costs. Based on these costs, the Manufacturer Analysis predicts retail prices for use in the consumer analysis (the Life-Cycle Cost Analysis and Forecasts). Based on the relationship between the prices and efficiencies of design options, the consumer analysis forecasts sales and efficiencies of new and replacement appliances. These data are used as inputs to the Manufacturer Analysis to determine financial impacts on typical firms within the industry. The consumer analysis also forecasts energy savings and consumer expenditures for the purchase and operation of the appliances. Consumer expenditures are used in the Life-Cycle Cost Analysis to determine consumer impacts. Changes in sales, revenues, investments, and marginal costs of utilities are calculated from the energy savings in the Utility Analysis.

Three time frames are considered by the analysis. First, the analysis of consumer and utility impacts extends over a time frame consistent with the life of the products and includes the time required to approach market saturation. This time frame extends to 2030 and the standards come into effect in 1996. Second, the Manufacturer Analysis is performed for a typical year after the imposition of standards. Third, the Engineering Analysis examines the technical feasibility of improving the efficiency of appliances before the standards come into effect—within the next three years.

3.3 MODELS, DATA, AND ASSUMPTIONS

3.3.1 Engineering Cost and Performance Models

The Engineering Analysis provides information on efficiencies, manufacturing costs, and other appliance characteristics for use in other components of the analysis. Appliance features that provide utility to the consumer are incorporated into the analysis through the creation of appliance classes. Classes are a subset of appliance types. For example, a water heater is an appliance type, but a gas-fired storage water heater is an appliance class. The Engineering Analysis develops cost and efficiency data for a set of design options within each appliance class. These data are the output of the engineering performance and cost models discussed later in this section. The Engineering Analysis is performed in seven steps: (1) select appliance classes; (2) select baseline units; (3) select design options within each class; (4) determine maximum technically feasible designs; (5) calculate the efficiency improvement provided by each design option; (6) develop cost estimates; (7) generate cost-efficiency relationships.

Appliance Classes

The first step in the Engineering Analysis is the segregation of product types into separate classes to which different energy-efficiency standards apply. DOE differentiates classes by the type of energy used (oil, natural gas, or electricity), and capacity or performance-related features that provide utility to the consumer and affect efficiency. For specific appliances, classes are defined using data collected in discussions with appliance manufacturers, trade associations, other interested parties, and from comments received on the Advance Notice of Proposed Rulemaking.

Those classes for which no DOE test procedure has been specified are omitted. The appliance classes covered by the analysis are listed in Chapter 1 of each product-specific volume.

Baseline Units

A baseline unit is the starting point for analyzing design options for improving energy efficiency. To select a baseline unit, the Engineering Analysis uses information gathered from trade organizations, manufacturers, consultants with expertise in specific product types, and from public comments on the Notice of Proposed Rulemaking. For each product class, the baseline unit generally represents a model with the maximum allowable energy use specified by the National Appliance Energy Conservation Act (NAECA). Other than efficiency, features are representative of the class as a whole.

Design Options

The Engineering Analysis identifies individual or combinations of design options with a potential for improving energy efficiency. Design options that are commercially available at the present time or that are present in prototypes are considered. They are selected after discussions with experts and an extensive literature review. The efficiency improvement and manufacturer cost of design options added to the baseline unit are calculated.

Maximum Technologically Feasible Designs

For each product class, a maximum technologically feasible design option or combination of design options is identified. This option, or combination of options, results in the highest energy efficiency for each product class. The maximum technologically feasible efficiency level is one that can be reached by the addition of design options, both commercially feasible and in prototypes, to the baseline units. This design must be possible to assemble, but not necessarily to manufacture in large numbers. Economic criteria are applied to all design options in other parts of the analysis.

Efficiency Calculation

For each of the product classes, the efficiency levels corresponding to various design options are determined from manufacturer data and from engineering calculations.

Cost Estimates

The manufacturer cost data are obtained through a lengthy process that included meetings and tours at manufacturing facilities, submission of formal requests to manufacturers for costing data, and review of the data received. Estimates of manufacturer cost are also received in response to the Notice of Proposed Rulemaking. In each product-specific volume, Appendix A contains detailed incremental cost data disaggregated into labor, purchased parts, materials, shipping/packaging and tooling.

Cost-Efficiency Relationships

The results of the Engineering Analysis are summarized in the cost-efficiency relationships showing the efficiency and manufacturer cost of the design options for each appliance class. Manufacturer and dealer markups derived in the Manufacturing Analysis are applied to the factory costs to arrive at the purchase price of the appliance. Additional installation costs required for some designs are included in the purchase price. Additional maintenance costs associated with specific design options are also estimated. The price-efficiency relationships are a fundamental input to the Consumer Analysis.

Assumptions in the Analysis

Justifications for the most important assumptions of the Engineering Analysis are listed below.

<i>Assumption</i>	<i>Justification</i>
<ul style="list-style-type: none">• Industry production processes can be characterized in terms of medium and large manufacturing facilities.	Manufacturing costs for small manufacturers are highly varied because of dependence on purchased parts and sensitivity to labor and distribution costs. An effort was made to obtain these data, but they were not made available by small firms. Because of this difficulty and the fact that they represent a small fraction of total shipments for most of the product classes, analysis concentrated on the medium and large manufacturers.
<ul style="list-style-type: none">• Baseline units can be selected to represent typical product offerings within a class.	The baseline unit is the starting point to which design options are added to create higher efficiency units. The selection of baseline units is based on studies of products on the market in 1990 and consultations with manufacturers.
<ul style="list-style-type: none">• Unit energy consumption is based on DOE usage estimates, unless otherwise noted.	As part of the Consumer Product Efficiency Standards program, DOE was required to establish test procedures to determine average consumer utilization and energy usage for the covered products. Test procedures for each product type have been promulgated and were employed to determine unit energy consumption throughout the Engineering Analysis.

Data Sources

Shipment data are based on information from industry sources and published data from industry trade associations. Costs of purchased materials and parts are based on quotations from product manufacturers and suppliers of these items. Data on engineering and labor costs are taken from on-site visits to manufacturing plants and from manufacturer information. Data characterizing baseline units for each class are based on information from industry sources and published data.

Outputs from the Engineering Analysis

For each combination of design options considered in the analysis, the models and data provide:

- energy efficiency (expressed as the DOE energy factor³ and/or unit energy consumption);
- increased material, labor, and investment costs by product class for medium and large manufacturers;
- annual energy consumption per unit (based on DOE test procedures);
- the relationship between cost and energy use by product class; and
- other information on product characteristics such as appliance lifetimes, installation costs, and maintenance costs.

Validation of the Results

Experimental data on efficiencies are available for some of the design options studied. For the others, engineering calculations based on physical principles are performed.

3.3.2 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 (1).

³The energy factor is a measurement of energy efficiency derived from the DOE test procedure for each product.

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. There are four groups of decision-makers, each with a different discount rate. 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. 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.

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; these densities are then converted to EUIs using building operating hours developed from EIA data (2).

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 policies 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 policy is the net energy impact.

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,⁴ 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. (2)

Calibration

As a first step in the calibration process, comparisons between COMMEND inputs and NBECS 1986, EIA's *Annual Energy Outlook 1991* (AEO) (3), and *State Energy Data Report Consumption, 1960-1989* (SEDR) (4) 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.

Baseline Forecasts

As described in Volume B, Chapter 2, 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.

⁴15 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 (see "Representation of Policies" below for a discussion of standards implementation in the model).

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 Environmental Protection Agency (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.

Representation of Policies

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

3.3.3 LBL Residential Energy Model (LBL-REM)

Purpose

The LBL-REM models the appliance purchase choices made in households, as well as these households' subsequent usage behavior and energy consumption. See Appendix B for details about the model.

Engineering, economic, and demographic data are used in LBL-REM. The engineering data for appliances are described in Section 3.3.1. Additional data include engineering data regarding alternative building shell construction measures and costs, unit energy consumption and efficiency of appliances, age distribution of existing appliance stock, and retirement functions. Economic data include projected energy prices and household income and models of energy investment, appliance purchase, and usage behavior (including fuel and technology choice for each end use).

Demographic data include number of households by type, projected housing starts and demolitions, and appliance holdings.

Historical Development

Early energy-demand modeling focused on engineering estimates or on the relationship between energy consumption and economic growth. In the 1970s, Oak Ridge National Laboratory (ORNL) developed the first model to integrate these two important aspects of energy demand, the Engineering-Economic Model of Residential Energy Use. (5)

The ORNL Model was brought to LBL in 1979 and adapted to the analysis of federal appliance conservation standards. Further extensive changes were made at LBL from 1979 to the present, resulting in the LBL-REM.(6) Many of these changes have already been documented. (7) More recent changes for this rulemaking are described in Appendix B.

Structure of the Model

The LBL-REM segments annual energy consumption into house types, end uses, and fuel types. The house types include single-family, multifamily, and mobile homes. Calculations are performed separately for existing and new housing construction each year during the forecast period, 1980-2030.⁵ The end uses are space-heating (including room and central), air-conditioning, water heating, refrigeration, freezing, cooking, dish-washing, clothes-washing, clothes-drying, televisions, lighting, and miscellaneous. Up to four fuels are considered, as appropriate to each end use: electricity, natural gas (utility gas), heating oil, and liquid petroleum gas (LPG). The national version of the model, which treats the country as a single region, is used in the analysis.

The model projects five types of activities: technology/fuel choice, building shell thermal integrity choice, appliance efficiency choice, usage behavior, and turnover of buildings and appliances. The interrelationship of the five types of activities is shown in Figure 3.2.

⁵ The model forecasts beginning in 1980. Historical data from 1980-1990 are used to check the validity of the forecast.

LBL RESIDENTIAL ENERGY MODEL

Figure 3.2 Activities in the LBL Residential Energy Model

Housing Stock Submodel

This submodel prepares data about the housing stock projection for the main model. The initial number of occupied households, by type, is taken from the 1980 Census of Population and Housing and an exogenous projection of housing starts is obtained. The housing submodel determines the projected housing stock for each year from 1981-2030 by house type, based on the projected age distribution of the population in each state. The method is described fully in Appendix B.

Efficiency Choice Algorithm

Historical efficiency data are available for selected years through 1991 for each of the eight products. After 1991, efficiency improvements are projected as a function of designs available (technological change) and of electricity, oil, or gas prices. If energy prices increase, the life-cycle cost of more efficient designs will increase more slowly than that of less efficient designs, making the more efficient designs more attractive. When the life-cycle cost of a more efficient design falls below the life-cycle cost of the current average design, then the more efficient design is projected to be purchased. Conversely, if energy prices decline, the model projects no further efficiency change.

Thermal Integrity

The projection of investment in thermal integrity measures in new houses is based on a life-cycle cost calculation analogous to that done for equipment efficiencies.⁶ Engineering estimates of the incremental costs of thermal integrity measures are used together with current fuel prices and a market discount rate for each house type and heating fuel type.

Modeling Efficiency Standards

The LBL-REM projects the average efficiency of new products, e.g., gas-fired water heaters, purchased each year in the absence of additional federal regulations, as described above. A distribution of unit energy consumptions (UEC) is constructed around the projected average unit energy consumption for each class, based on efficiency distributions previously observed in the marketplace. New federal standards would eliminate at least part of the distribution. A new distribution is constructed in which all sales below the standards are increased in efficiency to meet the standards. The new shipment-weighted average efficiency then characterizes the efficiency of new units in that year. The same process is applied to all years after implementation of the standards. The model is then run again, for the standards case, with the adjusted average efficiencies, to calculate any changes in market shares, usage behavior, or investment in building shell thermal improvements that may occur as a result of standards, and to calculate the net energy savings.

⁶ The equipment efficiency and thermal integrity decisions are not solved simultaneously, but recursively. The previous year's thermal integrity is assumed in projecting this year's equipment efficiency; then this year's equipment efficiency is used to calculate this year's thermal integrity.

Turnover of Appliance Stocks

The initial age distribution of appliances in stock is characterized from industry data about historical annual shipments and retirements. The fraction of each product that retires each year is based on the number of years since purchase for each age cohort.⁷ Each age cohort is associated with an average efficiency; when older appliances retire, they are also typically recognized as less efficient.

The number of potential purchasers of an appliance in new homes is equal to the number of new homes constructed each year. The number of potential purchasers in existing houses is equal to the number of retiring appliances, plus some fraction of those households that did not previously own the product.

Calculation of Market Shares

Potential buyers may make no purchase or may buy any competing technology within an end use. For each of the eight products, the decision to purchase or not is modeled, and the fraction of the total that choose each class, e.g., gas-fired, oil-fired, electric, or gas instantaneous water heaters, is specified exogenously. Long-term market share elasticities have been assumed with respect to equipment price, operating expense, and income. Standards are expected to create lower operating expenses and increased equipment prices. The percentage changes in these quantities are used, together with the elasticities, to determine changes in market share resulting from standards. Higher equipment prices will decrease market shares, while lower operating expense will increase market shares. The net result depends on the standard level selected and associated equipment price and operating expense.

Usage Behavior

For some products, changing the operating expense results in changes in usage behavior. These changes are modeled with usage elasticities in operating expense and income. For fluorescent light ballasts, televisions, water heaters, and pool heaters, these elasticities are assumed to be zero. For ranges and ovens, room air conditioners, direct heating equipment, and mobile home furnaces, these elasticities are assumed to be non-zero.

⁷ For example, a cohort consists of all 8-year-old gas-fired water heaters. Up to 30 cohorts, one for each year of purchase, are tracked for each purpose.

Energy Consumption Calculations

The total energy consumption per house for each end use and fuel by house type and vintage (existing or new) is the product of the UEC per cycle (accounting for efficiency changes) and usage factor, e.g., cycles per year. The corresponding energy consumption for all households is the consumption per house times the number of households of that type and vintage, times the fraction of households that owns that appliance.⁸

Aggregate energy consumption is obtained from summations over intermediate results. For example, national electricity consumption for residential water heaters in a particular year is the sum, over house types, classes, and vintages, of electricity consumption by water heaters. National residential electricity consumption in that year is the sum of electricity consumption over all end uses.

Assumptions in the Analysis

The Consumer Analysis assumes that decisions on the purchase and use of appliances depend on operating expenses, household income, and appliance prices. Manufacturers are projected to respond to the demand for more efficient products by incorporating technologically feasible and cost-effective design options in new units. Exogenous forecasts of population growth, housing starts, personal income and energy prices from published sources are utilized. Justifications for the most important assumptions in the Consumer Analysis are listed below.

⁸ For space-conditioning (heating and cooling), two additional terms are multiplied by the intermediate results: relative floor area (square feet of conditioned space), and relative thermal integrity (a measure of the effect of building shell characteristics on energy consumption).

Assumption

- Population growth is projected to follow Census projections to the year 2000 and population growth is projected to slow from 2000 to 2015.
- The fraction of the population in each age group in each state that lives in a particular house type is projected to remain constant over time.
- Housing starts in future years are projected to range from 900,000 to 1,100,000 single-family units; 300,000 to 530,000 multifamily units, and 170,000 to 210,000 mobile homes.
- Real disposable personal income is projected to grow from \$3.9 trillion in 1990 to \$7.7 trillion in 2030 (in 1990 dollars). This corresponds to disposable personal income per household growing from \$41,500 in 1990 to \$59,400 in 2030.
- In real terms, residential electricity prices are projected to increase at an average annual rate of 0.3% from 1989 to 2010, and 0.6% from 2011 to 2030. Residential natural gas prices are projected to increase at an average annual rate of 2.1% from 1989 to 2010, and 2.2% from 2011 to 2030. Residential distillate prices are projected to increase at an average annual rate of 1.5% from 1989 to 2010, and 1.3% from 2011 to 2030.

Justification

A Census projection of population by state, by age group, benchmarked to the 1980 Census count, provides the basis for the projection to 2000. The projection given in the 1985 OBERS BEA Regional Projections is consistent with Census projections to 2000 and shows slower growth after 2000.

As the age distribution and the geographic distribution of the population change, the mix of house types will also change.

A long-term forecast from Data Resources, Inc., represents a state-of-the-art projection for single-family and multifamily units. The projection for mobile homes is based on the population projection.

The DOE/EIA *Annual Energy Outlook 1991* (8) provides the projection to 2010, which is extrapolated to 2030. The extrapolation is linear, based on the 2010 to 2015 trend.

The DOE/EIA *Annual Energy Outlook 1991* provides the projection to 2010.

Assumption

- Appliance purchase decisions are based on operating expenses, as well as on equipment price.
- Manufacturers are projected to respond to consumer demand for energy efficiency. Engineering designs that are technologically feasible and attractive to purchasers are assumed to be available.
- Thermal integrity of homes is projected to continue to improve.
- The lifetimes of appliances are projected to remain the same as empirically observed in the past, independent of energy efficiency.

Justification

Research on equipment sales for competing alternatives and on historical efficiency choices indicates that operating expenses are significant variables.

Industry is competitive and historically has responded to changes in consumer demand. No evidence suggests an end to the responsiveness.

Increasing energy prices and awareness on the part of consumers have resulted in modified construction practices and in home retrofits. Building codes under consideration, utility company incentives, and projected long-term energy price increases suggest that further thermal improvements are likely.

Retirement functions are based on reconciliation of appliance stocks and shipments. Lifetimes may include engineering and economic determinants, which are not separated in existing studies.

Data Sources

The LBL-REM takes the energy efficiencies of new equipment from the Engineering Analysis. The purchase price of these products is derived from the factory cost supplied by the Engineering Analysis and adjusted for manufacturer and dealer markups in the Manufacturer Analysis. Data on housing and equipment stocks as well as historical data on housing starts and new equipment purchases come from the 1980 census and industry trade associations. Exogenous projections of population, housing starts, income, and energy prices are taken from Census, Data Resources, Inc., and DOE, respectively. Appendix B contains a more detailed discussion of the data used in the model.

Model Outputs

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

- Energy consumption by end use and fuel;
- Per-unit equipment price and operating expense by product;
- Total residential energy consumption by fuel;
- Projected annual shipments of residential appliances; and
- Differences in these quantities between a base case and each standards case.

These outputs are provided annually (or for selected years) and cumulatively for the period 1996-2030. Energy savings from implementation of standards are provided annually to the end of the period. Net present value (NPV) of standards is evaluated for each regulated product and for the end use(s) comprising the regulated and competing products.

Cost-Benefit Analysis

The costs and benefits of the proposed standards from a national perspective are quantified by calculating a net present value. The NPV is the sum of discounted savings in operating expenses minus the sum of discounted increases in equipment prices.

DOE has determined that 6% real is the appropriate discount rate for calculating benefits to the consumer. The NPV of standards is also calculated at consumer discount rates of 2% and 10% as sensitivity analyses.

Different assumptions about technology choice are invoked when calculating energy savings of standards on the one hand, and when calculating the net present benefit of standards on the other. Energy savings are the net of any adjustments households make in changing their technology or fuel choice or from using appliances differently. For example, if, after standards, a regulated product captures larger market shares (without displacing consumption of another fuel), then the net energy savings will be diminished. The energy savings are calculated as the net result of standards, accounting for such secondary effects as shifts in market share.

NPV excludes these secondary effects. Base case purchase behavior, without market share changes, is assumed in calculating the NPV, because any market share shift reflects the consumer's judgment that change is worth more than the direct energy savings associated with keeping market share constant. NPV is calculated from per unit changes in equipment and operating costs, multiplied by standards case shipments. If the NPV was calculated without normalizing to shipments, the results would be erroneous: if standards caused decreased purchase of a product, this would appear as an economic benefit, namely less money spent on purchasing

and use of the appliance;⁹ and (2) if standards caused an increase in purchases, this would be counted incorrectly as a cost, when it reflects consumers' preference for the post-standards product.

3.3.4 LBL Manufacturer Impact Model (LBL-MIM)

Conceptual Approach

The Manufacturer Impact Analysis estimates both the short- and long-run impacts of new or amended standards on profitability (return on equity) and many other variables for each industry under consideration. All computations used in this analysis are carried out by the Manufacturer Impact Model (LBL-MIM), which is a spreadsheet composed of thirteen modules. Figure 3.3 lists these and displays their interactions. In addition to computing estimated values for the above-mentioned descriptive variables, the LBL-MIM also computes standard errors for each by explicitly evaluating the standard errors in the estimates of input variables and then using Monte Carlo simulations.

Measures of Impact

Three types of long-run impacts are analyzed: (1) profitability, (2) growth, and (3) competitiveness. To do this, the following five measures of impact are tracked for the industry: (1) shipments, (2) price, (3) revenue, (4) net income, and (5) return on equity (ROE).

ROE is the primary measure of profitability, although gross margin, return on assets, and return on sales are also reported. Changes in assets and revenue are the measures of growth (positive or negative). Because all the industries analyzed are in an historical process of consolidation, any decrease in ROE will tend to hasten this process; thus, ROE also provides an indication of the impact of standards on competitiveness.

A short-run calculation is also made. If the long-run calculation indicates a decrease in sales, the predicted price is reduced by an amount determined by the industry's observed behavior during historical downturns in sales. The adjusted price is used to calculate the other measures of impact.

⁹ Without normalization, the greatest economic benefit would be obtained by standards that resulted in no future purchases of the product. Then, no money would be spent on purchasing the product, or on operating expenses, and the value of the savings would equal the amount of money that would have been spent without the standards. Clearly, this would be a misrepresentation of the NPV of standards.

Figure 3.3 Conceptual Approach to the Manufacturer Impact Model

Figure 3.4 How Standards Cause a Change in ROE.

Description of the LBL-MIM

Although LBL-MIM examines many aspects of an industry, its most important job is to compute the effect on profits of a cost increase caused by standards. To accomplish this, the model first estimates how much of the cost increase is passed on in the form of higher prices. (An accompanying effect is the decrease in operating expense due to standards, which makes the product more desirable to the consumer and, thus, increases demand for the product.) Then, it estimates how this price increase and the accompanying reduction of operating expense influence demand. Finally, given the new price and level of demand, it computes a new level of profit. These calculations use estimated long-run costs. The LBL-MIM makes an additional calculation to correct for any short-run difficulties the industry may have in achieving its long-run markup.

It is important to note from the start that the model does not assume perfect competition, nor does it assume that the level of profit will remain unchanged. The results of the model depend entirely on the input values.

The basic behavior of the model can be understood only in light of the following standard economic consideration. In the long run, an increase in *fixed costs will not be passed on* via a price increase except when it is sufficient to cause some firms to leave the industry.¹⁰ This result is derived from the assumption that firms act individually to maximize profits and from the definition of fixed costs as those that are not proportional to output. The mathematical derivation is given in Appendix C of this volume.

A second influence on profits is the change in purchases resulting from both the change in price and the change in operating expense. These tend to offset each other because price increases lower quantity demanded, and increased efficiency increases demand (by lowering operating expense). The LBL-MIM takes these effects into account through the use of two demand elasticities which play an important role in determining the outcome and are therefore examined more closely in the sensitivity analysis.

Assumptions in the Analysis

This section begins with a series of short discussions of different aspects of the modeling procedure that require careful interpretation (such as "long-run variable cost") or simplifying assumptions. This is followed by a list of more detailed assumptions.

The long-run costs. The LBL-MIM requires input of long-run costs. A firm is in long-run equilibrium when it has optimal productive capacity. Thus, during a recession (when firms experience excess capacity), firms are not in long-run equilibrium, and the theory of price as a markup over long-run costs may not apply. Long-run fixed costs are those that remain unchanged when a firm moves from one long-run equilibrium to another; they do not include

¹⁰ When firms leave the industry, it becomes less competitive and the remaining firms can increase their markup over variable costs, thus, indirectly covering their increased fixed costs.

capital costs that are proportional to output. The latter are considered long-run variable (marginal) costs and are marked up and passed on. To the extent that costs are not strictly proportional to output, but decrease on average with quantity produced, there are fixed costs. Also, a cost that does not depend on the scale of production, i.e., an engineering cost, is a long-run fixed cost.

Use of "typical" firm. The analysis estimates the impact of the standards by using "typical" firms. A typical firm is a hypothetical firm that is described by industry-average values. Each one is modeled as if it produced only products of the industry being analyzed. This procedure is justified by the observation that real firms generally are organized into autonomous divisions, each of which produces a different type of appliance and one of which generally corresponds to the industry being modeled. Also, these divisions are generally run on a profit-and-loss basis similar to a firm. It is not possible to analyze inter-divisional interactions within real firms.

Aggregation. Generally, it has been impossible to obtain data on cross-elasticities of the various product lines within an industry. Therefore, data for the various products are aggregated before the markup is computed and applied. However, once the aggregate calculations have been made, individual prices are computed for the various classes of products.

How standards are implemented in the model. A change in standards affects the model in three distinct ways. In general, stricter standards will require additional investment, will raise production costs, and will affect revenue through both price and demand.

The most obvious investment induced by standards is the purchase of new plants and equipment. This cost is first evaluated from engineering data, and then amortized by taking into account the life of the investment, the date at which it is made, tax laws, and the appropriate cost of funds. An additional, and sometimes larger, investment takes place as the old inventory is replaced with more expensive new units. The model assumes that the ratio of inventory to revenue remains unchanged; in this way both changes in quantity sold and unit value are taken into account. A third form of investment tracked by the LBL-MIM is the change in the demand for cash that accompanies a change in revenues.

Financial inputs. Several simplifying assumptions are used in the process of generating inputs for the LBL-MIM. First, all firms within a particular industry segment (e.g., large manufacturers of water heaters) are assumed to have the same cost structure. Second, it is assumed that financial data collected for the parent company are representative of the specific product division being studied. These data come from publicly available sources such as Value Line, Standard and Poor's, Moody's, and company reports.

Impact Analysis: An Overview

The next section provides a general discussion of the methods of the impact analysis together with some cautions about interpreting the results. Most, but not all, of the discussion applies to all eight products.

The significance of long-run impacts and how they are analyzed are discussed below. These impacts are most important simply because they will either persist or be so severe as to cause a restructuring of the industry. The meaning and analysis of short-run impacts are also discussed. Additionally, the various types of sensitivity analysis performed on the model's results are discussed. This analysis is crucial for understanding the accuracy and reliability of the model's predictions, and includes the use of alternative scenarios, sensitivity checks on individual inputs, and Monte Carlo simulations involving the random selection of all control inputs.

3.3.4.1 Long-Run Impact Analysis

Implementation

The heart of the model is the long-run impact analysis. It assumes that enough time has passed for any changes in demand to have been accommodated by changes in the industry's productive capacity. Thus, in the long-run, capacity, or capital stock, is variable. Because capital is sometimes thought to be the only fixed cost, it might seem that fixed costs would be zero in the long run. This is not the case. For the purpose of price determination, whenever there are returns to scale, there are, effectively, fixed costs. This means that if the cost of meeting standards is less than proportional to plant capacity, there are fixed costs. Design costs would typically fall into this category. See Appendix C.2.1 of this volume for a more detailed discussion of the long run.

The fraction of increased costs of production (due to more stringent standards) that manufacturers are able to pass on is determined by the nature of the cost, i.e., whether it is fixed or variable, the price elasticity of demand, and the consumer discount rate as seen by the price-setting firm. Once the price increase has been determined, it and the operating expense decrease (obtained from engineering data) are used with the price elasticity of demand and the discount rate to determine the change in sales. These mechanisms are presented in Figure 3.4, which displays the most basic economic forces analyzed by the LBL-MIM.

Instead, the reduction in operating costs makes the appliance more desirable, thereby shifting the demand curve out (e.g., an increase in production costs changes the marginal cost curve). Together, these determine price and the number of units shipped (quantity). Price and quantity, together with production costs, determine net income (profit), and these, together with changes in capital stock (not shown), determine return-on-equity (ROE).

As shown in Figure 3.4, the two cost changes do not translate directly into price changes.

The LBL-MIM simulates standards as follows. For each product, a set of engineering designs is specified. For each design, the engineering analysis provides a per-unit cost, a one-time capital cost, and an energy usage. The two costs effectively determine the production costs used in Figure 3.4 and the energy usage determines the operating expense. The Manufacturer Impact Model calculates a weighted average of the two costs and the energy usage for the relevant engineering designs. The weights used correspond to the relative numbers of shipments for each engineering design as determined by LBL-REM.

Another and more subtle point is that markup is determined by price elasticity, and because life-cycle-cost elasticity is constant, price elasticity changes with a change in either price or operating expense. This change in markup can have an important impact on ROE.

The markup discussed here is a markup over *economic* variable costs, which is a broader category than the typical business definition of variable costs. The manufacturer markup listed in the model and the technical support document is used only to calculate the baseline model price (calculated by multiplying the baseline manufacturer cost by the manufacturer markup). This is called the calibration case in LBL-MIM. The manufacturer markup listed is *not* used in calculating the manufacturer prices for the 1996 base case or the standard levels. In these cases, the manufacturer price is calculated from the economic markup¹¹, which, as described above, is dependent on elasticities, discount rates, and price and operating expense changes. Thus prices at different standards levels do not exactly reflect the manufacturer cost times the manufacturer markup.

Typical results of an analysis of a standard at a particular level might be the following: wholesale price increases 10%, sales decline 2%, revenue increases 8%, net income increases 12%, and ROE increases 0.5%. Associated with each of these numbers is a standard error. The errors might be as follows: 4% on price, 1% on sales, 4% on revenue, 10% on net income, and 1.5% on ROE. To interpret the prediction for ROE, one could then conclude (by checking a table of the normal distribution) that there is about a 69% chance that ROE will increase, and a 31% chance that it will decrease. One could also conclude that the chance of profits declining by more than 2% is only 2.3%.

3.3.4.2 Short-Run Impacts

In the shortest run, capacity is fixed; however, the short run of interest is, at the shortest, approximately three years. During this time some change in capacity may occur, and demand, apart from the change induced by standards, will change. Demand for each appliance is projected to grow by approximately 2% during the three years, so to that extent it will alleviate any tendency toward excess capacity resulting from standards.

¹¹For a thorough description of how markups are derived and used in LBL-MIM, see Appendix C.2.1.

In order to simplify the analysis and to take a cautious approach, the analysis has ignored the ability of the industry to actively or passively adjust its capacity relative to demand. The estimated short-run effect is what would happen if the industry converted, as a result of standards, all of its present capacity, and if the demand curve did not shift except as an indirect consequence of standards.

The short-run analysis is based on the analogy between a change in demand caused by standards and one caused by the business cycle. The business cycle periodically presents the industry with a fairly sharp decrease in demand that is much greater than the decrease predicted for any of the standards levels. This demand shortfall seems to present all of the opportunities for price competition that would accompany a shortfall resulting from a change in standards. Data for the last few business cycles (18 years) have been analyzed to determine the ratio between the decline in demand (industry-wide) and the induced decline in price.

If, for example, the long-run prediction is for a decline in demand of 2%, then, using the above figure, the short-run price could be predicted to be 0.06% ($0.03 \times 2\%$) lower than the long-run price. Actually, this is just a first approximation, and the model does better, as follows: the short-run price response factor (SRPR) of 0.03 means that the short-run price will be 0.06% lower than predicted with the long-run price formula if the *actual* decline in demand is 2%. This is different from the long-run prediction of a 2% decline, because the short-run price fall will keep the long-run demand fall from fully materializing. Thus, in the short run, the actual fall in demand will be less than the long-run prediction of 2%, and the actual fall in price will be greater than the long-run prediction, but not by a full 0.06%. Short-run demand and price must be determined simultaneously, which occurs in the short-run module of LBL-MIM.

Short-run prices, profit levels, and other variables will gradually, over a period of several years, approach their long-run values. How long this will take depends on the industry, on the fact that the implementation of standards is announced three or four years in advance, and on how fast (and if) the demand for the product is growing. These factors are discussed in the sections on individual products.

3.3.4.3 Sensitivity Analysis

Both because of the nature of the information required and the desire of sources to protect proprietary information, many of the data used by the model represent uncertain estimates. Therefore, the effect of these uncertainties on the accuracy of the model's predictions is analyzed. Two types of questions need to be answered. First, how does a particular input variable contribute to the uncertainty of the outputs? Second, how uncertain is the estimate of a particular output variable?

Sensitivity charts

The model's sensitivity to inputs is measured by the impact of a change of one standard error (S.E.) in the input variable. This analysis is presented only for the impact of input variables on ROE; this standardizes and simplifies the process. The results are displayed in a sensitivity chart, an example of which is given and explained below.

Table 3.2 Sensitivity of ROE to 1 S.E. Change in Control Variable, Direct Heating Equipment

Scenario = Primary							
Control Variables			Possible Standards Levels				
Name	Value	Changed	1	2	3	4	5
IPE	-0.300	-0.690	0.06%	0.07%	0.15%	-1.65%	-4.27%
RD	50.00%	114.96%	0.00%	0.15%	0.22%	1.32%	2.81%
ECC	0.068	0.075	0.00%	0.00%	0.00%	-0.01%	-0.04%
EP	0.008	0.018	-0.01%	-0.01%	-0.02%	0.07%	0.15%
FCA	0.098	0.157	0.00%	0.00%	-0.01%	0.06%	0.13%
F1X	0.200	0.348	-0.09%	-0.10%	-0.14%	-0.17%	-0.30%
CC.N	0.394	0.480	-0.02%	-0.03%	-0.04%	-0.07%	-0.16%
dVC.N	5.124	6.872	0.00%	0.01%	0.01%	0.05%	0.01%

Table 3.2 lists the sensitivities of ROE to the control panel inputs defined below:

1. IPE is the industry price elasticity.
2. RD is the consumer discount rate.
3. ECC is the firm's real equity cost of capital.
4. EP is the firm's economic profit.
5. FCA is the percentage of a firm's costs that are fixed before standards.
6. F1X is the percentage of one-time costs (i.e., costs that are induced by standards) that are fixed.
7. CC.N is the estimate of one-time capital costs induced by standards.
8. dVC.N is the increase in variable costs necessary to reach a standards level.

Note that for CC.N and dVC.N the change of one standard error from the mean is applicable for standards level 2 only. These two variables are dollar values rather than percentages, and thus their value and the change in one standard error are different at each standards level.

To construct the table, each control variable is first set to its normal value. Next, one at a time, each is increased in absolute value by one standard error and the change in profit is recorded. Then the variable is returned to its normal value and the next variable is tested. The matrix in the table lists the percentage point change in ROE as a result of the change of one standard error in the variable's value. The change in ROE is listed for each control panel variable and at each standard level being analyzed.

Since each variable has its own standard error, the sensitivity reported in the table measures both how sensitive the model is to a change in the variable, and how uncertain the variable's value is. Note that the change in profit is simply the difference between long-run ROE and base case ROE. Note also that, as expected, increasing the absolute values of some variables increases ROE and, for other variables, decreases ROE.

The comparison of the various inputs' contributions to the uncertainty in ROE focuses attention on the parts of the model that should be examined most closely to determine their accuracy and on the parts where improvement in the certainty of input variables would have the greatest payoff. Because of the differences in the sensitivities among input variables, it will generally be found that one to three of the inputs will dominate the model's uncertainty, in the sense that perfecting all the rest of the inputs would make only a negligible difference to the model's accuracy.

Alternative Scenarios

For each appliance class and hypothetical standards level, hundreds of different scenarios are run for the Monte Carlo analysis described in a following section. However, a few scenarios that involve different demand elasticities are singled out for special attention.

If the reader wishes to estimate some other scenario not reported here, he or she can often simply use the sensitivity charts. To do this, first look up how sensitive ROE is to a one standard deviation change in the control variables that are changed by the proposed scenario. Then estimate by how many standard deviations the desired scenario variables differ from the primary scenario control variables and calculate a proportional change in ROE. Lastly, add the changes in ROE resulting from the different variables. This method should be reasonably accurate for changes in the control variables that are likely to be of interest.

Uncertainty of Outputs (Monte Carlo Analysis)

Output uncertainty is most directly addressed by the Monte Carlo analysis. This analysis assigns an uncertainty to each of the nine control-panel input variables and then chooses a value for each based on this uncertainty. The model is then solved using these randomly chosen

variables. All of the important outputs are tabulated on the Monte Carlo page of the model. These outputs are changes from the base case of price, shipments, revenue, net income, long-run ROE, and short-run ROE. Next, new values of the input variables are drawn from the same distribution. The model is run again and the new outputs recorded. This cycle can be repeated as many as 400 times (or more). After a sufficient number of runs, the mean and standard deviations of each output variable are computed.

The standard deviations of the Monte Carlo output variables are the best estimate of the true uncertainty of the model's predictions. However, this does not mean they are absolutely reliable because they are based on estimates of the uncertainty of the inputs, and these are often not based on something as objective as the standard error of a regression coefficient. In short, if the uncertainty in the inputs is misperceived, the estimate of uncertainty in the outputs cannot be relied upon. Nonetheless, the standard errors generated by the Monte Carlo procedure are useful for the interpretation of the LBL-MIM outputs.

Assumptions in the Analysis

<i>Assumption</i>	<i>Justification</i>
<ul style="list-style-type: none">• Firms maximize revenues minus economic costs ($R-EC$), where EC includes the cost of equity and all taxes.	This follows from the assumptions of standard economic theory, in which firms are rational profit maximizers.
<ul style="list-style-type: none">• The life-cycle-cost elasticity of demand experienced by a single firm is constant. This means that price elasticity will tend to decrease with operating cost. Note also that since price elasticity is finite, firms have market power.	There is no reason to assume that life-cycle-cost elasticity either increases or decreases with cost; thus, constancy is the base assumption.
<ul style="list-style-type: none">• Costs are assumed to have two components: one fixed, and one proportional to quantity.	A linear cost function approximates any smooth curve over a small region; since quantity changes very little with standards, the linear approximation should be adequate.
<ul style="list-style-type: none">• Assets are assumed to be a linear function of sales.	Same as previous justification.
<ul style="list-style-type: none">• The debt-to-equity ratio remains constant while the firm finances any investment necessary to meet standards.	Firms attempt to maintain a relatively constant overall debt-to-equity ratio, which they believe is optimal. Although specific new expenditures (such as those induced by standards) may be financed primarily by debt or by equity, in the long run the debt-to-equity ratio will be restored to its desired value.
<ul style="list-style-type: none">• The additional costs of parts, materials, and labor are assumed to be long-run marginal costs.	These costs are proportional to production except for cases in which there are discounts for large quantity purchases. Industry sources state that at the scales of production under consideration, these discounts are very nearly exhausted.

Assumption

- A percentage (that varies from industry to industry) of capital costs are long-run fixed costs.
- Any fall in demand caused by standards (because of a price increase) will affect prices in the industry by the same amount as a normal fall in demand experienced during the business cycle.

Justification

Although industry informants have stated that one-time capital costs will be proportional to the production capacity of the plant in question, it seems inevitable that there will be some associated engineering costs that are not. These will be long-run fixed costs.

To the extent that a normal demand shortfall reduces the firm's short-run marginal cost, the demand decrease caused by standards will be indistinguishable. The crucial assumption here is that the business cycle does not influence the consumers' elasticity of demand. There is no evidence one way or the other on this.

Outputs of the LBL-MIM

The LBL-MIM tracks five essential output variables, with emphasis on ROE. The other four variables are price, sales, revenue, and net income. Base case and short- and long-run values of these variables are reported on the control panel. In addition, LBL-MIM constructs an output table that shows the long-run values of the variables at each of the standard levels under consideration. LBL-MIM also produces a simplified income statement. As part of its algorithm, it calculates the markup from manufacturers' costs to consumer purchase price. The purchase price is used in the calculation of price-efficiency curves, the life-cycle-cost curves, and the calculation of payback periods, and throughout the LBL-REM.

All of these values are estimates that necessarily reflect some uncertainty. Estimates of these uncertainties and identification of their sources comprise another set of model outputs. Under each estimate of one of the five main output variables, the output table displays that variable's change from its base level and the standard error of the estimate of that change. The LBL-MIM also computes the effect on ROE of a one-standard-deviation change in each of the control variables. This is reported for each standard level in a sensitivity chart, designed to help discover the source of uncertainty in the output variables.

Data Sources

The LBL-MIM needs data that characterize both a particular industry and typical firms within that industry. Estimates of data are based on information from five general sources: (1) the Engineering Analysis, (2) the Consumer Analysis, (3) industry consultants, (4) public financial data, and (5) industry profiles. A detailed discussion of model inputs for each product appears in Appendix C for that product's volume.

3.3.5 Utility Impact Model

The Utility Analysis serves several purposes in the assessment of the impact of the proposed standards. It contributes to quantifying energy savings by determining the reduction in fossil fuels used for electricity generation; this reduction also serves as input to the Environmental Assessment. By calculating utility avoided costs, the Utility Analysis provides marginal electricity costs to be used in evaluating the societal benefits of standards. The Utility Analysis also quantifies impacts on the electric utility industry's need for new generating capacity. Finally, the Utility Analysis calculates net impact of standards on utility revenues. Appendix E of this volume contains more information on the model and data used to perform these calculations.

The Utility Analysis adopts the convention that the value of electricity savings can be broken down into energy (or marginal cost) savings and reliability (or capacity) savings. The energy impact measures production costs avoided by reduced electrical demands, valued at the marginal energy costs of the utility. The reliability impact measures the value of reduced loads during system peak periods, which is, by convention, valued at the cost of a combustion turbine. This convention is justified in Appendix E. The analysis calculates the avoided costs per kWh of energy saved. These values are used to calculate societal benefits from reduced electricity consumption.

The utility impact model calculates avoided energy costs based on a disaggregation of the generation fuel mix to the National Electric Reliability Council (NERC) regions and a simplified load duration curve for each region. First, the model allocates national electricity savings forecast by the LBL-REM to NERC regions in proportion to their 1980 consumption of heating, cooling, and baseload energy. For the three product types under consideration, only baseload energy is used. The fraction of the electricity that would have to be generated at the margin from oil and gas is calculated from total regional oil and gas generation and the simplified load duration curve. Projected utility natural gas and coal prices, weighted by the oil and gas marginal fraction and the non-oil and gas marginal fraction, respectively, are used to calculate utility marginal energy costs during the forecast period.

The avoided-capacity cost calculation in the model is based on conservation load factors (CLFs) for the energy savings attributable to the standards, as well as the cost of a combustion turbine. A conservation load factor is defined as the average load savings of a conservation measure (in kilowatts) divided by its peak-load savings. The peak savings are averaged over an

on-peak period from 8 A.M. to 8 P.M. This wide on-peak period yields a conservative estimate for peak-load savings that accounts for coincidence with system peak demand.

The CLFs, calculated using annual average appliance load curves from Southern California Edison Company data, are used to characterize the peak demand savings of a conservation measure. (4) They are used to convert the reliability value of the standards into the per kWh values described above. The analysis assumes that the load shapes of each one of the eight product types do not change as these appliances are made more efficient.

The NERC forecasts of capacity requirements for each region are used to account for regional variations in reserve margin. If NERC predicts an adequate reserve margin in a region for a given year, no reliability value is given to the peak load savings in the region.

The net revenue loss is equal to the difference between the revenue reductions and avoided costs. Revenue reduction is calculated by multiplying the change in electricity consumption by the average utility rate. Avoided costs are calculated from the change in electricity consumption multiplied by the per-unit, avoided costs.

The inputs needed for the utility impact model include electricity savings, conservation load factors, state-level utility fuel prices, average electricity prices, appliance saturations, efficiencies, hours-of-use, and electricity generation by fuel type and capacity need by NERC region. The outputs of the analysis are the fuel savings, the reduction in the need for new generating capacity, the net change in revenues, and the avoided energy and capacity costs for heating, cooling, and baseload appliances per million Btu of resource energy. These marginal costs are used to calculate societal costs and benefits of standards.

Assumptions in the Analysis

Justifications for the most important assumptions in the Utility Analysis are listed below. These assumptions include the shape of regional load-duration curves, factors that remain constant through the analysis, the regional distribution of energy savings, utility marginal costs, and the substance of NERC forecasts.

Assumption

- The analysis calculates the period during which oil and gas or coal are the marginal fuels for electricity generation based on a simplified load duration curve (LDC) for each NERC region. It therefore assumes that this LDC accurately reflects the distribution of fuels on the margin.
- The oil and gas fractions (OGFs) calculated for all the NERC regions remain constant throughout the analysis period.
- Energy savings accrue in each region in proportion to the region's consumption of heating, cooling, and baseload energy in 1980.

Justification

There is little information by NERC region on which fuels are marginal. Since NERC supplies the total amount of fuel burned for generation, a method is needed to convert total generation into an estimate of marginal generation, and using an LDC is the usual way to derive such an estimate. Because oil and gas are most expensive, they will be used by utilities to meet the peak load-hours; hence, oil and gas are assumed to be at the top of the load duration curve. The other fuel on the margin is coal, since nuclear and hydro resources are usually base-loaded.

Constant OGFs are assumed to simplify computation. The OGFs are calculated using the simplified LDCs described above and by averaging NERC forecasts of the total amount of oil and gas generation for the years 1990 to 1995. There are no forecasts for the amount of oil and gas generation after 1995. Because these calculations are highly uncertain, and because no other forecasts are available, the analysis assumes constant OGFs.

This approach is an approximation made necessary by insufficient information and for computational convenience. Information is available on average saturations and appliance efficiencies, by state, that can be aggregated to NERC regions.

Assumption

- Utility marginal energy costs are calculated using the sum of utility natural gas and coal prices weighted by the oil and gas fraction and the non-oil and gas fraction, respectively. This approach assumes that all marginal generation has the same heat rate.
- The NERC forecasts of changes in adjusted reserve margin are accurate.

Justification

Different generating units have different heat rates, but the extent of this variation for utility generating systems in different NERC regions has not been calculated. A 10,000 Btu/kWh heat rate is typical for many different types of generating units.

The NERC forecasts are widely accepted. They are the only forecasts of adjusted reserve margin at the regional level.

3.3.6 Life-Cycle Cost Analysis

One measure of the effect of proposed standards on consumers is the change in operating expenses as compared to the change in purchase prices. These changes are quantified by the difference in life-cycle costs between the base and standards cases for the appliance classes analyzed. The LCC is the sum of the purchase price and the operating expense discounted over the lifetime of the appliance. It is calculated at the average efficiency for each class in the year standards are imposed using real consumer discount rates of 2%, 6%, and 10%. The purchase price is based on the factory costs in the Engineering Analysis and includes a factory markup plus a distributor and retailer markup. Maintenance and installation costs are included, when appropriate. The operating expense is calculated using the unit energy consumption data in the LBL-REM. Energy prices and appliance usage are taken from the results of the LBL-REM. The life-cycle cost analysis also examines the payback periods and the cost of conserved energy associated with the standards. Details of the LCC calculation may be found in Chapter 4 of each product-specific volume.

An additional measure of economic impact, payback period, is useful in evaluating the impacts on consumers of efficiency standards. The payback period measures the amount of time it takes to recover additional investment in increased efficiency through lower operating costs. Numerically, it is the ratio of the increase in purchase price between the base and standards cases to the decrease in annual operating expenditures. Both the numerator and denominator of this expression are evaluated at the average efficiency in the year standards come into effect and at energy prices in that year.

3.4 SENSITIVITY ANALYSIS

Sensitivity studies are performed to determine how changes in technical and operational parameters affect key engineering and economic indicators used in the evaluation of appliance standards. This makes it possible to place bounds on the uncertainty in the results of the analysis and to gain an understanding of which variables are most important in producing these results. Sensitivity analyses are developed in a series of distinct steps. For each computer model in the analysis, critical input parameters are identified and reasonable ranges of variation are determined. The sensitivity of the model to changes in the value of each important parameter is then estimated by running the model for the base case and standards cases. The significance of the results is assessed in terms of the magnitude of change in each model's outputs.

Sensitivity runs are made with the LBL-REM to explore the effects of uncertainty in the equipment and operating cost of the products being analyzed. The costs of the baseline unit as well as the incremental costs of design options are varied. Other sensitivity runs examine alternative efficiency trends in the absence of new standards.

Sensitivity analysis of the results of the LBL-MIM is conducted mainly from a sensitivity chart that reports the sensitivity of ROE to each of the nine control variables. Because the LBL-MIM is a non-linear model, the effects of these input uncertainties may not be additive. A Monte Carlo analysis addresses this problem by computing standard errors, which are displayed in the output table. For each control variable, the Monte Carlo section randomly picks a value near the best estimate of its true value. As a result, the outputs of Monte Carlo vary from run to run. After finishing a batch of runs (typically 100 to 400), the LBL-MIM calculates means and standard deviations for the five main output variables.

The results of the sensitivity analyses are examined to extract two types of information. First, the base case runs of the model are analyzed to determine the sensitivity of the forecasts to exogenous variables and assumptions. Second, the sensitivity analysis of the impacts of standards is performed by examining the differences between the base and standards cases. A variable that affects the two cases similarly will have little effect on the impact of standards, even though it might have a significant effect on the absolute forecasts. The primary interest in the second type of sensitivity analysis is in variables and assumptions that affect the two cases differently. The sensitivity analyses of the impacts of standards are discussed in the chapters on these impacts.

The EPRI COMMEND sensitivity run for the fluorescent ballast analysis was the "*High-Efficiency* baseline." Standards analyzed under the reference baseline ("*Base Case*") show the savings potential if other existing incentives (utility DSM, EPA's Green Lights, and FEMP's Relighting Initiative) are removed from the market after 1995. Standards analyzed under the "*High-Efficiency* baseline" show the effects of the persistence of existing incentives programs after 1995. The savings for the sensitivity run are less than those for the reference case, reflecting the smaller magnitude of available savings to be captured by standards. See Volume B, Chapter 2, for further explanation of the commercial sector baselines.

CHAPTER 4. INDUSTRY PROFILE FOR LBL-MIM ANALYSIS

This section begins by examining housing starts and appliance saturation rates, with the primary focus on annual unit shipments for each of the analyzed products. It then presents a brief description of market shares followed by a discussion of mergers and acquisitions in these industries, and finally a comparison of consumer and producer price indices.

4.1 DEMAND

Units Shipped and Housing Starts

One of the primary components driving the demand of most appliances is housing starts. Although the changes in shipments of appliances are not entirely the result of changes in housing starts, housing starts can be used to predict shipments of most appliances for two reasons. First, almost every new house requires a new set of appliances, so fluctuations in housing starts cause fluctuations in shipments of most common appliances. (In fact, most of the fluctuation in shipments of products being analyzed can be attributed to the fluctuations in housing starts.) Second, housing starts are a good indicator of the strength of the economy as a whole. A healthy new-housing market is likely to correspond to a healthy economy, and a healthy economy encourages replacement and discretionary purchases of appliances. Therefore, there is generally a strong correlation between new-housing starts and appliance shipments. For similar reasons, there are strong (if not even stronger) correlations between mobile home production and the sales of mobile home furnaces, and between new commercial floor space and fluorescent lamp ballast shipments.

Figures 4.1 through 4.8 show annual shipments compared to housing starts between 1970 to 1989 for most products. Figure 4.7 shows mobile home furnaces versus new mobile home production. Figure 4.8 shows annual fluorescent lamp ballast shipments and new commercial construction between 1980 and 1989. There is a strong correlation between housing starts and sales of many of these appliances, which is seen clearly in the nearly exact parallel of the graphs in the figure.

Other factors such as age of the current stock of appliances, purchase prices, fuel costs, consumer incomes, and climate conditions have varying degrees of importance in determining shipments of the various products covered by the National Appliance Energy Conservation Act of 1987 (NAECA). Further, some appliances have strong demand in the replacement market or in the aftermarket, and thus would be less correlated with new housing starts. Some of these factors are used by the LBL-REM in predicting appliance shipments in the base case and new standards case. The Manufacturers Impact Analysis uses the LBL-REM estimates in its analysis of financial impacts on manufacturers.

As expected, most of the appliances show a strong correlation with housing starts. Several interesting points emerge from these graphs. In the case of direct heating equipment (Figure 4.2), there is a strong correlation with housing starts from 1969 to 1979 for the total (primarily composed of wall furnaces with lesser correlations for room heaters). From about 1978 to the present, the shipments of direct heating in general (and floor furnaces in particular) have been declining. Meanwhile, the shipments of central heating equipment have been rising and probably have been absorbing the market share of direct heating equipment. This observation corresponds with reports from the industry which also state that the primary market for direct heating equipment is now replacement rather than new sales.

The explosive growth in microwave ovens is displayed in Figure 4.3. After a slow period of growth in the late 1960s to early 1970s, the popularity of microwave ovens increased steeply in the 1980s, probably due in part to the greater convenience, improvement of the technology, and lower prices. In fact, the saturation rate of microwave ovens rose from 1% in 1973 to 66% in 1987, according to industry trade sources.

The sales of room air conditioners have little correlation with housing starts. We expect that this is because room air conditioners are bought primarily in the aftermarket and have a strong seasonal component in their purchase.

Similar to microwave ovens, television sets have experienced explosive growth over the twenty years as noted in Figure 4.5. In particular, color televisions have greatly outstripped the sales of black-and-white televisions.

Appliance Saturation Rates

The saturation rate is the percentage of homes that own a particular appliance. Tables 4.1 and 4.2 list the saturation rates for the various analyzed appliances in selected years during the past 20 years. Note that the data do not reflect the fact that some homes have more than one appliance of a particular type. In general, if most homes own an appliance but few homes have more than one unit, we expect that the appliance will have a relatively low elasticity of demand because the appliance is usually considered a necessity. This observation corresponds with the relatively low price elasticity of certain products such as water heaters and ranges and ovens and the higher price elasticity of products such as televisions and microwave ovens.

Figure 4.1 Range & Shipments Compared to Housing Starts

Figure 4.2

Direct Heating Equipment Shipments Compared to Housing Starts. DHE = Direct Heating Equipment.

Source: GAMA and Current Industrial Reports
Figure 4.3 Water Heater Shipments Compared to Housing Starts

Source: Appliance and Current Industrial Reports

Figure 4.4 Microwave Shipments Compared to Housing Starts

Source: *Appliance and Current Industrial Reports*

Figure 4.5

Room Air Conditioner Shipments Compared to Housing Starts

Source: *Appliance and Current Industrial Reports*

Figure 4.6 TV Shipments Compared to Housing Starts

Source: NCSBCS and the industry.

Figure 4.7 Mobile Home Furnaces Compared to Mobile Home Production.

Source: COMMEND, PNL, and Current Industrial Reports

Figure 4.8

Fluorescent Lamp Ballast Shipments Compared to New Commercial Floorspace

Table 4.1. Market Saturations

Product	1973 %	1978 %	1983 %	1987 %
Room Air Conditioners	30	28	27	26
Water Heaters (Electric)	46	48	47	46
Water Heater (Gas)	53	52	53	53
Ranges (Electric)	47	51	58	59
Ranges (Gas)	52	48	43	42
Microwave Ovens	1	7	33	66
Televisions (Color)	67	85	93	96

Source: *Appliance*, September 1989.

Table 4.2. Market Saturations*

Product	1981 %	1984 %	1987 %
Pool Heaters (Gas)	0.6/0.5	1/1	2/3
Direct Heating Equipment	6/0.4	5/0.4	4/0.5
Color Television Sets	87/88	88/88	93/97
Electric Stove	54/29	54/79.5	57/77
Electric Oven	52/74	49/73	57/75
Gas Stove	46/21	45/20	2.7/21
Gas Oven	40/17	42/18	41/21
Microwave	17/23	34/51	61/76
Room Air Conditioners	32/17	30/19	30/16

Source: RECS, 1981, 1984, 1987.

*Initial figure is for the stock of dwellings, the second is for new construction. RECS figures include mobile homes, and single-and multi-family dwellings.

4.2 SUPPLY

Market concentration

Market concentration is the extent to which market share is controlled by the largest firms in an industry. Table 4.3 shows the market concentration for the products according to the degree of the market controlled by the two, four, and five largest producers in each industry.

Most of the products show a high level of market concentration. With the exception of microwave ovens and television set manufacturers, the markets concentration of the top five producers are at least 85%. The largest producer controls from 40% to more than 50% of the market for each of these products. Market concentration plays a part in the analysis because it may indicate the existence of market power¹² in a particular industry. Firms with the largest market shares may have some market power, a factor that affects the markups used by these firms both in the base case and the standards case.

Table 4.3 Percent of Market Controlled by the Largest Producers of Each Product

Product	Number of Companies		
	Top Two %	Top Four %	Top Five %
Water Heaters	49	87	100
Ranges (Electric)	60	92	99
Ranges (Gas)	52	92	95
Microwave Ovens	35	61	70
Room Air Conditioners	55	81	87
Fluorescent Ballasts	60	95	100
Pool Heaters	66	96	100
Direct Heating Equipment (Room)	54	80	86
Direct Heating Equipment (Wall)	77	92	96
Direct Heating Equipment (Floor)	48	79	89
Televisions	35	55	62

Figures 4.9 to 4.18 give a picture of the manufacturer market shares for each of the eight products. Most products are produced by a few manufacturers, each of which have large market shares.

¹²Market power is the ability to set price within a limited range. More technically, it is the freedom that results from facing a demand curve that is not infinitely elastic. This means that if price is raised by some small amount, sales will not fall to zero, and if price is lowered by some small amount, sales will not become essentially infinite.

Water Heater Firm Market Shares - 1991

Source: *Appliance Manufacturer*

Figure 4.9 Water Heater Firm Market Shares-1991

Electric Range Firm Market Shares - 1991

Maytag owns the Jenn-Air, Hardwick, and Magic Chef brand names
Electrolux owns the Frigidaire and Tappan brand names
Raytheon owns the Caloric brand name.
GE includes what was Roper.

Source: *Appliance Manufacturer*

Figure 4.10 Electric Range Firm Market Shares—1991

Gas Range Firm Market Shares - 1991

Source: *Appliance Manufacturer*

Figure 4.11 Gas Range Firm Market Shares-1991

Microwave Oven Firm Market Shares - 1991

Source: *Appliance Manufacturer*

Figure 4.12 Microwave Oven Firm Market Shares—1991

1991 RAC Firm Market Shares

Source: *Appliance Manufacturer*

Figure 4.13 Room Air Conditioner Firm Market Shares—1991

1990 Fluorescent Lamp Ballast Firm Market Shares

Source: Lighting Research Institute

Figure 4.14 Fluorescent Lamp Ballast Firm Market Shares—1990

Pool Heater Firm Market Shares - 1991

Source: Discussions with the industry and LBL staff.

Figure 4.15 Pool Heater Firm Market Shares—1991

Direct Heating Equipment Room Heater Firm Market Share 1991

Source: Industry consultant and LBL staff.

Figure 4.16 Direct Heating Equipment: Room Heater Firm Market Share—1991

Direct Heating Equipment Wall Heater Firm Market Shares 1989

Source: Industry consultant and LBL staff

Figure 4.17 Direct Heating Equipment: Wall Heater Firm Market Share—1989

Direct Heating Equipment 1989 Floor Furnace Firm Market Shares

Source: Industry consultant and LBL staff

Figure 4.18 Direct Heating Equipment: Floor Furnace Firm Market Shares –1989

4.3 MERGERS AND ACQUISITIONS

The appliance-manufacturing industry has had a continuing history of consolidation. Mergers and acquisitions have two purposes: First, they produce large corporations with the financial resources and stability to be successful in an increasingly competitive market. Second, mergers and acquisitions mean manufacturers can have a complete line of home appliances for product diversification and can therefore offer a complete set of appliances to consumers, an important feature in the builder market. There is increasing worldwide competition in the major appliance market, so mergers or acquisitions are likely to continue. Table 4.4 is a partial list of major acquisitions of appliance manufacturers covered in this analysis.

Table 4.4 Acquisitions of Appliance Manufacturers

Buyer	Purchase	Year
Whirlpool	Heil-Quaker	1964
Raytheon Co.	Amana Refrigeration, Inc.	1965
White Consolidated Inc.	Franklin Appliance Div. (Studebaker Corp.)	1967
White Consolidated Inc.	Kelvinator Appliance Div. (American Motor Corp.)	1968
Emerson Electric Co.	In-Sink-Erator	1968
Magic Chef, Inc.	Gaffers & Sattler	1968
Magic Chef, Inc.	Dixie-Narco, Inc.	1968
Magic Chef, Inc.	Johnson Corp.	1971
AB Electrolux (Sweden)	Eureka	1974
Rockwell International	Admiral Co.	1974
White Consolidated Inc.	Westinghouse Electric Corp.'s Major Appliance Operations	1975
Caloric Corp. (Raytheon)	Glenwood Range Co.	1978
White Consolidated Inc.	Philco Appliance Business (Ford Motor Co.)	1979
White Consolidated Inc.	Frigidaire Appliance Business (General Motors Corp.)	1979
Magic Chef, Inc.	Admiral Div. (Rockwell)	1979
Carrier	Jenn-Air	1979
Raytheon Co.	Modern Maid Co.	1979
Raytheon Co.	Speed Queen (McGraw Edison)	1979
United Technologies Corp.	Carrier	1979
AB Electrolux (Sweden)	Tappan	1981

Table 4.4 Acquisitions of Appliance Manufacturers - Con't.

Buyer	Purchase	Year
Dart & Kraft	Hobart Corp.	1981
Magic Chef, Inc.	Revco	1981
Maytag Co.	Hardwick Stove	1981
Maytag Co.	Jenn-Air (Carrier/United Techn)	1982
Hobart (Dart & Kraft)	Chambers Corp. (Rangaire Corp.)	1983
Magic Chef, Inc.	Toastmaster	1983
Admiral (Magic Chef)	Warwick Manufacturing Co.	1985
Chicago Pacific Corp.	The Hoover Co.	1985
Masco Corp.	Thermador-WasteKing (NI Ind.)	1985
AB Electrolux (Sweden)	White Consolidated Industries	1986
Maytag Co.	Magic Chef, Inc.	1986
Chicago Pacific Corp.	Rowenta Group (West Germany) (Allegheny Int'l and Rothmans Deutschland GmbH)	1986
Whirlpool Corp.	Kitchen-Aid Division (Dart & Kraft, Inc.)	1986
General Electric Co.	RCA	1986
Inter-City Gas Corp. (Canada)	Heil-Quaker Home Systems, Inc. (Whirlpool)	1986
Emerson Electric Co.	Kitchen-Aid dishwashing manufacturing facility (Whirlpool)	1986
White Consolidated Ind. (Electrolux)	Design & Manufacturing Corp.	1987
Thomson S.A. (France)	GE/RCA consumer electronics	1988
Toastmaster Div.	Mgt. team buys division from Maytag Co.	1988
Speed Queen	Holiday-Hammond	1988
Whirlpool Corp.	Roper Corp.'s brand name	1988
General Electric Co.	Roper Corp.'s physical assets (inc. manufacturing facilities)	1988
Maytag Co.	Merger with Chicago Pacific Corp.	1988
Fedders	Emerson Quiet Kool	1990
Hayward Pools	ComfortZone	1991

4.4 PRICES

Appliance prices have, on average, risen more slowly than aggregate indexes measuring consumer and producer prices, with direct heating equipment being an exception, and television sets showing a strong drop in the 1980s. The appliance industry has a long history of price stability even through fluctuations in the business cycle. Despite increased energy and component prices during the 1970s and 1980s, the industry has, through increased productivity, kept price increases lower than increases in the Consumer Price Index (CPI). In recent years, the industry has made a strong push toward automation to keep costs down, spending hundreds of millions of dollars to automate production facilities.

Figure 4.19 shows the Producer Price Index (PPI) for all commodities and for household appliances for the years 1984 to 1991. The PPI for household appliances increased about half as much as the PPI for all commodities. Figures 4.20 to 4.25 show the real PPI for various product groupings compared to the CPI and the household appliance group as a whole. The real PPI for each product grouping is defined as the PPI for that product grouping, holding the overall PPI constant at 1982 = 100. In other words, this figure indicates the relative increase or decrease in the price index of a product grouping, using the PPI for all commodities as the yardstick. The subsequent figures and their products are

- Figure 4.20: Household Cooking Equipment (kitchen ranges and ovens and microwave ovens),
- Figure 4.21: Household Audio and Video Equipment (including TVs),
- Figure 4.22: Refrigeration and Heating Equipment (including RACs),
- Figure 4.23: Household Appliances Not Elsewhere Classified (including water heaters),
- Figure 4.24: Heating Equipment, Except Electric and Warm Air Furnaces (including direct heating equipment and pool heaters), and
- Figure 4.25: Power, Distribution, and Specialty Transformers (including fluorescent lamp ballasts).

Source: U.S. Bureau of Labor Statistics

Figure 4-19 National PPI and CPI for All Household Appliances

Figure 4.20 National CPI and PPI Averages Compared to Household Cooking Equipment PPI
4-27

Source: U.S. Bureau of Labor Statistics

Figure 4.21 National CPI and PPI Averages Compared to TV Product Group PPI

Figure 4.22 CPI and PPI National Averages Compared to RAC Product Group PPI

Figure 4.23 National CPI and PPI Averages Compared to Water Heater Product Class PPI

Figure 4.24 National CPI and PPI Compared to DHE and Pool Heater Product Group PPI

Figure 4.25 National CPI and PPI Averages Compared to Ballasts Product Group PPI

CHAPTER 5. DEVELOPMENT OF BASE CASE FORECASTS

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 impact of standards.

Projections are made for a number of demographic, economic, and energy variables, which hold true for all end uses, including energy prices, household income, housing stock, housing starts, mix of house types (single-family, multifamily, mobile homes), and building shell thermal characteristics. Additional (product-specific) variables, described in Chapter 2 of each product-specific volume, include appliance purchases, equipment prices, unit energy consumption, and aggregate residential energy consumption by fuel type.

5.1 ECONOMIC AND DEMOGRAPHIC DATA: RESIDENTIAL

The LBL-REM (described in Volume A, Appendix B) is used to derive projections of residential energy demand. These projections are dependent on assumptions about future years, including the size and age distribution of the population, number of annual housing starts, disposable personal income, and energy prices. These data are described in Tables 5.1 through 5.6. (Economic data specific to each product, such as equipment price, initial market shares, elasticities for market shares, efficiency choices, and usage behaviors are described in Appendix C of each product-specific volume.)

5.1.1 Population Projection

The population projection for the U.S. is based on Bureau of Census data to the year 2010 (10). The population projections are consistent with those used by DOE in projecting energy prices. Projections for later years are obtained by extrapolation, assuming that the annual rate of increase in population is at 0.5% per year from 2010 to 2030.

5.1.2 Occupied Households

The number and type of occupied households for the base year (1980) are from the 0.1% Public Use MicroSample (PUMS) of the 1980 Decennial Census. The population projection is used to estimate the housing stock in each state each year, as described in Appendix B.

Table 5.1 Demographic Projections

	U.S. Population (millions)	Occupied Households (millions)	Single- family (millions)	Multi- family (millions)	Mobile Homes (millions)
1980	226.9	80.4	53.8	22.7	3.9
1985	238.1	87.1	58.4	24.5	4.2
1990	249.9	94.4	63.3	26.5	4.6
1995	259.6	101.3	67.9	28.4	5.0
2000	267.7	107.8	72.3	30.3	5.3
2005	275.1	114.3	76.6	32.1	5.6
2010	282.1	117.2	78.5	32.9	5.8
2015	289.2	120.1	80.5	33.7	5.9
2030	311.7	129.5	86.8	36.4	6.4

Source: U.S. Department of Commerce, Bureau of the Census.

5.1.3 Housing Starts

Single-Family and Multifamily

Figures for past (1980-1985) housing starts by state come from the National Association of Home Builders (NAHB) data (11). Projections (1986-2015) by region come from Data Resources, Inc (12). Housing starts in later years (2016-2030) are based on changes in the housing stock and estimated retirement rates, described in Appendix B.

Mobile Homes

Past mobile home placements for residential use are taken from the U.S. Bureau of Census (1980-1986) data. In other years, mobile home placements are calculated from changes in the projected stock of mobile homes and estimated retirement rates.

Table 5.2 Housing Starts, 1980-2015 (Thousands)

	Single- family	Multi- family	Mobile homes	Total
1980	852	460	222	1534
1985	1072	670	283	2025
1990	895	298	200	1393
1995	1056	531	214	1801
2000	1021	403	200	1624
2005	937	414	192	1543
2010	909	443	183	1535
2015	901	444	177	1522
2030	971	478	191	1640

Sources: (1980-1985) NAHB; (1986-2015) Data Resources Inc.; (2016-2030) LBL.

Table 5.3 House Retirement Rates (Percent of Stock per Year)

Single-Family	0.62%
Multifamily	0.82%
Mobile Home	2.50%

5.1.4 Disposable Personal Income

Disposable personal income (1980-1986) is from the *Survey of Current Business* (13), converted to 1990 dollars using the Consumer Price Index-Urban. For 1987-2015, the projection from the *DOE Annual Energy Outlook 1991* is used (14), similarly converted to 1990 dollars. For 2016-2030, the projection is extended, assuming a linear increase in disposable personal income, with the annual increase being the average of the increases from 2010 to 2015.

Table 5.4 Disposable Personal Income (1990 Dollars)

	Total (Billions)	Per Occupied Household (Thousands)
1980	2890	35.9
1985	3435	39.4
1990	3916	41.5
1995	4227	41.7
2000	4665	43.3
2005	5126	44.8
2010	5592	47.7
2015	6056	50.4
2030	7692	59.4

Sources: (1980-1986) *Survey of Current Business*; (1987-2015) DOE/EIA *Annual Energy Outlook 1991*; (2016-2030) LBL extrapolation.

5.1.5 Residential Energy Prices

Past energy prices (1980-1988) are from the DOE *Monthly Energy Review* (15). Energy prices for 1989 and 1990 as well as projected energy prices (1991-2010) are from DOE *Annual Energy Outlook 1991* (13). Extrapolation of energy prices (2011-2030) assumes average annual increases of 0.6% per year for electricity, 2.2% per year for natural gas, 1.3% per year for distillate, and 2.2% per year for LPG.

Electricity prices are further adjusted to reflect differences in effective price by specific end uses. Table 5.6 shows multipliers for obtaining effective prices for space heating, water heating, air conditioning, and other end uses from the average sector prices in Table 5.5.

These multipliers capture regional differences in residential rates and appliance holdings, as well as effects of rate structure. (For example, if electric heat is common in areas with lower residential rates, then the effective rate for electric space heating is lower than the average residential rate. Also, if the block structure offers declining rates for increased consumption, then end uses associated with higher consumption, including space heating, will have lower effective rates.) The multipliers are derived from the 1987 Residential Energy Consumption Survey.

Table 5.5 Average Residential Energy Prices (1990 Dollars per Million Btu)

	Electricity ¹	Natural Gas	Distillate Oil	LPG
Past				
1980	22.44	5.71	11.16	12.37
1985	27.75	7.21	9.41	9.25
1990	23.74	5.69	7.64	8.31
Projected				
1991	23.87	5.76	7.57	8.41
1992	24.01	5.84	7.51	8.52
1993	24.14	5.91	7.45	8.63
1994	24.27	5.98	7.38	8.73
1995	24.41	6.06	7.32	8.85
1996	24.28	6.15	7.39	8.98
1997	24.15	6.25	7.45	9.12
1998	24.02	6.34	7.52	9.26
1999	23.90	6.44	7.59	9.40
2000	23.77	6.54	7.66	9.55
2005	24.74	7.98	8.65	11.65
2010	25.44	8.90	9.24	12.99
2015	26.16	9.93	9.87	14.49
2020	26.90	11.07	10.54	16.16
2025	27.66	12.35	11.26	18.02
2030	28.44	13.77	12.03	20.10

¹3412 Btu/kWh.

Source: (1980-1988) DOE *Monthly Energy Review*.

(1989-2010) DOE/EIA *Annual Energy Outlook 1991*.

(2011-2030) extrapolated by LBL.

Table 5.6 Relative Electricity Price by End Use (Average Residential Electricity Price = 1.00)

	Electricity	Natural Gas
Space Heating	0.90	0.98
Water Heating	0.90	0.98
Air Conditioning	1.00	NA
Other End Uses	1.04	1.20

Source: LBL derived from 1987 RECS.

5.2 ECONOMIC AND DEMOGRAPHIC DATA: COMMERCIAL

EPRI COMMEND (described in Volume A, Appendix B) provides projections of commercial energy demand. These projections depend upon commercial floorspace, GNP, and energy prices. Appendix C of Volume B describes the inputs specific to lighting.

5.2.1 Commercial Floor Space Projections

Floor Space Data

Table 5.7 shows the forecasted total U.S. commercial sector floor space (including federal buildings) by building type used for this analysis, based on data developed by Pacific Northwest Laboratories (PNL) (16). Floor space growth drives the overall growth in demand for energy services in the COMMEND model.

Floor space values given by EPRI in the COMMEND default input files are slightly lower than the values published in the AEO 1992 (17), the NES (18), and the values used by PNL. Because these other sources are in close agreement, the PNL floor space data series was chosen in this study (as it provides the most detail). PNL data give the vintages of currently existing commercial buildings. The survival functions specified in COMMEND characterize the retirement rate of buildings and are used to estimate annual additions from 1920 to 1989. For the future, the growth rate of total commercial floorspace is related to the Gross National Product (GNP) growth rate through the regression equation calculated by PNL, which is based on data for 1963-1986.

$$\Delta \ln(S_t) = 0.117 \Delta \ln(\text{GNP}) + 0.863[\Delta \ln(S)]_{t-1} \quad (1)$$

where $\Delta \ln(S)$ = a dimensionless growth rate relating the stock S in the year t to the stock in the previous year, $t - 1$.

$$\Delta \ln S_t = \ln S_t - \ln S_{t-1} = \ln \frac{S_t}{S_{(t-1)}} \quad (2)$$

The GNP forecasting is based on DRI numbers (to the year 2000) published in the 1987 AEO (Case A). After the year 2000, a GNP growth rate of 2.1% per year is assumed (based on AEO 1992 projections), which yields a 1.8% annual growth in floor space. This total forecasted figure is distributed to building types based on a fixed ratio (the average of the last three years' additions distribution) and is kept constant throughout the forecasting period.

By the year 2030, 75% (98 billion sq ft) of the commercial floor space will have been built after 1986. All buildings, however, will have an opportunity for lighting system changes by 2030.

Table 5.7 Commercial Floor Space Projections (Billions of square feet)

Year	Small Office	Large Office	Restau- rant	Retail	Grocery	Ware- house	School	College	Health	Lodging	Misc.	Total
1980	4.95	4.95	1.18	11.55	0.81	8.10	6.35	2.71	1.87	3.31	10.52	56.30
1985	5.60	5.60	1.22	12.16	0.83	8.99	6.31	2.70	2.04	3.57	10.75	59.78
1990	6.13	6.13	1.29	13.06	0.88	9.96	6.52	2.80	2.20	3.81	11.25	64.02
1995	6.64	6.64	1.39	14.15	0.95	10.79	7.07	3.03	2.38	4.13	12.18	69.34
2000	7.21	7.21	1.51	15.37	1.03	11.72	7.68	3.29	2.58	4.48	13.24	75.34
2005	7.86	7.86	1.65	16.75	1.12	12.78	8.37	3.59	2.82	4.89	14.43	82.10
2010	8.58	8.58	1.80	18.28	1.23	13.94	9.13	3.92	3.07	5.33	15.74	89.60
2015	9.38	9.38	1.97	19.99	1.34	15.25	9.99	4.28	3.36	5.83	17.22	98.00
2020	10.25	10.25	2.15	21.85	1.47	16.67	10.92	4.68	3.67	6.37	18.82	107.12
2025	11.21	11.21	2.35	23.89	1.60	18.22	11.93	5.12	4.02	6.97	20.58	117.10
2030	12.25	12.25	2.57	26.11	1.75	19.92	13.04	5.59	4.39	7.62	22.49	127.98

Sources: PNL, DRI, NBECS, 1986.

5.2.2 Building Starts

Building starts are calculated using PNL 1989 commercial building data with historic vintage information on when buildings were built. These data, together with default COMMEND building decay functions, yield estimated commercial building starts listed in Table 5.8. The COMMEND building decay functions provide the building retirement rates shown in Table 5.9.

Table 5.8 Commercial Building Starts, 1980-2030 (Billions of square feet)

Year	Small Office	Large Office	Restaurant	Retail	Grocery	Warehouse	School	College	Health	Lodging	Misc.	Total
1980	0.166	0.166	0.026	0.300	0.017	0.265	0.067	0.030	0.040	0.077	0.184	1.338
1985	0.246	0.246	0.033	0.388	0.022	0.349	0.070	0.032	0.054	0.086	0.186	1.714
1990	0.126	0.126	0.040	0.363	0.032	0.128	0.223	0.099	0.046	0.085	0.359	1.626
1995	0.189	0.189	0.042	0.421	0.029	0.273	0.211	0.090	0.063	0.105	0.338	1.950
2000	0.211	0.211	0.047	0.477	0.032	0.307	0.236	0.100	0.069	0.120	0.377	2.188
2005	0.238	0.238	0.052	0.526	0.035	0.340	0.250	0.107	0.078	0.139	0.409	2.411
2010	0.261	0.261	0.055	0.561	0.037	0.379	0.264	0.113	0.088	0.157	0.441	2.617
2015	0.304	0.304	0.060	0.615	0.041	0.429	0.280	0.120	0.097	0.168	0.479	2.896
2020	0.327	0.327	0.066	0.678	0.045	0.475	0.292	0.126	0.104	0.177	0.514	3.131
2025	0.344	0.344	0.073	0.740	0.050	0.521	0.316	0.136	0.112	0.191	0.558	3.386
2030	0.375	0.375	0.080	0.810	0.055	0.557	0.351	0.151	0.122	0.208	0.609	3.693

Sources: PNL, COMMEND decay functions

Table 5.9 Building Retirement Rates

Building Type	Percentage		Percentage		Percentage	
	Age Years	Remaining %	Age Years	Remaining %	Age Years	Remaining %
Small Office	15	99	36	50	80	20
Large Office	15	99	36	50	80	20
Restaurant	15	99	36	50	80	20
Retail	15	99	36	50	80	20
Grocery	15	99	36	50	80	20
Warehouse	15	99	48	50	90	20
School	15	99	48	50	90	20
College	15	99	48	50	90	20
Health	15	99	48	50	90	20
Lodging	15	99	48	50	90	20
Miscellaneous	15	99	48	50	90	20

Sources: COMMEND default values

5.2.3 Commercial Energy Prices

Table 5.10 shows the energy price forecasts used in this analysis. Non-electric energy prices are important here because they affect the choice of heating energy in COMMEND forecasts, which ultimately influences the estimates of HVAC interactions. Real commercial prices for electricity, natural gas, and fuel oil used in the analysis are in constant 1990 dollars. Prices prior to 1990 are taken from the *EIA Monthly Energy Review* (MER), August, 1992.(18) Price forecasts are taken from the *EIA Annual Energy Outlook* (AEO), 1992, extrapolated to

2030. The deflator values for the years 1973-1990 are taken from the MER. For the years 1991-2030, the deflators are calculated based on the trend given by the input files supplied with the COMMEND program.

Electricity costs are projected prices for 1995 from the *Annual Energy Outlook 1991*. The commercial electricity price is \$0.0773 per kWh (1990 dollars).

For natural gas prices beyond 2010, the price trajectory from the National Energy Strategy (NES) (9) is used, scaled to the AEO 1992 price in 2010. This price path is based on output from the FOSSIL2 partial equilibrium model and incorporates information about the supply/demand balance for natural gas. The growth in natural gas prices is expected to flatten out in 2015, according to the NES prediction.

The default input files of COMMEND use the fuel oil price as an indication of the price level of petroleum products. This is improved by defining a mix of products (distillate fuel, kerosene, LPG, and residual fuel) and calculating a price index for this mix. The consumption levels given in the *State Energy Data Report, Consumption Estimates 1960-1989* (SEDR),(21) for the year 1989 are used to calculate the contribution of each product to the mix. It is assumed that propane represents all of LPG, fuel oil represents all of the distillates, and all of the residual oil used in the commercial sector is of low sulfur content.

electricity prices are 3% lower, while gas and distillate prices are 5% lower than those in the AEO 1991 forecast.

- *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.
- *High Equipment Efficiency.* Assume continuing future improvement in appliance efficiencies at a rate of 2% per year.
- *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 Sections 2.3 (base case sensitivity) and Sections 3.6 (standards impacts) of Volumes B through I.

5.3.2 Commercial Sector Sensitivity Cases

The sensitivity case for the commercial sector is defined as follows:

- *Lower Equipment Price/High Efficiency Case.* The price of energy-efficient lighting is lower, simulating continuing DSM (demand-side management) programs by electric utility companies or a permanent price drop by lighting manufacturers.

APPENDIX A. UNCERTAINTY ANALYSIS FOR ENERGY EFFICIENCY

Many of the inputs to the calculations of energy savings for each design option have some degree of uncertainty. This uncertainty of the inputs affects the level of confidence in the estimate of energy savings for design options. As design options are combined, the effects of the uncertainty on the inputs are also combined, so that the uncertainty in the energy savings becomes larger and larger.

In order to understand the effects that the uncertainty of input values had on the calculation of energy savings, a risk-analysis program (22) was used to quantify the uncertainty. The risk-analysis program was an add-in to the spreadsheets used to generate the cost/efficiency tables shown in the TSD (See Figure A.1.) It allowed the inputs to the calculations to be specified by an assumed distribution of values with associated probabilities. After the probabilities were specified, the energy-savings spreadsheet was recalculated several hundred times, randomly choosing a value from each distribution. The selection was done so that the distribution of input values chosen matched the probabilities specified in the input distribution.

The baseline was assumed to be exact for purposes of this study, therefore no distribution was applied to any of the inputs on the baseline models. The uncertainty on inputs for combined or stacked design options included, or were applied on top of, the uncertainties of previous design options. Often different design options affected different parts of the energy consumption calculations. An example of this would be applying heat traps to a gas-fired storage water heater and then applying a submerged combustion chamber. The heat traps reduce the standby loss, while the submerged combustion chamber increases the recovery efficiency. In these cases, the uncertainties from previous design options were used in the calculations, even though that part of the calculation was not being changed by the current design option.

The results of the uncertainty analysis were reported only for the maximum technologically feasible design options. These results include the uncertainties of all the design options that were applied before the maximum technologically feasible design option. The upper and lower values reported for the uncertainty of the efficiency indicator span the middle 95% of all values resulting from the uncertainty analysis.

For room air conditioners, the method was modified slightly to accommodate the use of a simulation model. An input file to the simulation model was constructed for the baseline and each design option. The data in the input files specified the properties and operating conditions of a room air conditioner. The risk-analysis program was used to generate several hundred simulation model input files. The distribution of values in the input files that were used to specify changes from the baseline by the design options reflected the probability distribution entered into the risk-analysis software. The combined results of all the simulation runs thus reflected the impact of uncertainty on the inputs.

Most of the input values were assumed to have a normal distribution, with the selected value being the mean of the distribution. The standard deviation of the distribution was then specified as the difference between the largest and/or the smallest values considered possible and the mean. The distributions were typically truncated at two standard deviations from the mean. This truncation excludes the smallest 2.28% and the largest 2.28% of the possible values in a normal distribution. This was done to eliminate potential outliers that could unnaturally skew the results.

Figure A.1 Schematic of @RISK Uncertainty Analysis for Spreadsheet Calculations

APPENDIX B. FORECASTING MODELS

B.1 LBL RESIDENTIAL ENERGY MODEL

B.1.1 Overview

The LBL Residential Energy Model (LBL-REM) provides projections of the important characteristics of the residential appliance market. The LBL-REM utilizes a database of significant determinants of the current residential appliance market, as well as parameters characterizing market decisions that will affect the energy consumption of future appliances. This appendix describes the LBL-REM, the types of data it uses, the calculations it performs, and the results the LBL-REM provides.

The LBL-REM projects numbers of households by house type, energy-related building shell characteristics, average energy efficiency of appliances, fraction of households owning each appliance, usage behavior, and turnover of appliances. These characteristics are projected for each year from 1980 to 2030.

The LBL-REM combines these factors to project energy consumption and expenditures by fuel type for each end use, and monetary expenditures for equipment (both replacement and new installations) and for fuels. The results are reported in several formats, for convenience, including: annual energy consumption and expenditures, annual equipment shipments, cumulative energy consumption and expenditures over a period (e.g., from policy implementation date to the end of the projection period), and net present values of equipment and energy expenditures, discounted and summed over time.

The basic equation in the simulation model that defines residential use of fuel i for end use k in housing type m during year t is:

$$Q_t^{ikm} = STOKC_t^m \times C_t^{ikm} \times EU_t^{ikm} \times U_t^{ik} \times TI_t^{ikm} \quad (B.1)$$

where $STOKC$ is the stock of occupied housing units, C is the saturation (percent of households with this equipment): EU is the unit energy consumption, U is the usage behavior factor, and TI is the thermal integrity factor (for space conditioning only).

Households respond to changes in operating expenses in three different ways. In the short run (see B.1.6, "Usage Behavior"), they change the way they operate existing equipment and structures (e.g., lower winter thermostat settings). In the long run, they also change equipment by switching from one fuel to another (see B.1.5, "Market Shares"), by improving the efficiency

of their equipment (e.g., purchasing a water heater with more jacket insulation (see B.1.4, "Equipment Efficiency"), or both. Thus, the elasticity of demand for a particular fuel with respect to the price of that fuel can be thought of as being separated into three elements—a usage elasticity (E_u), a technical efficiency elasticity (E_e), and an equipment/fuel choice (market share) elasticity (E_{ms}):

$$E = E_u + E_e + E_{ms} \quad (\text{B.2})$$

In fact, the LBL-REM also includes "cross-price" effects in the elasticity of market share E_{ms} , i.e., the effect of changes in the operating expense of one fuel on the market shares of competing fuels and technologies.

B.1.2 Housing

The housing submodel uses: (1) population projections, which are more stable than projections of housing completions because of the comparatively larger influence of economics on housing completions. In the long run, the number of housing units available is expected to agree with the need for housing units, which is determined by the size and composition of the population; (2) population projections for states by house type; and (3) uses projections of the number of people in each age group in future years to estimate changes in the distribution of house types.

B.1.2.1 Number of Households

The method for determining the number of households of each type in any future year has several steps. First, the 0.1% sample of the 1980 Census is analyzed to provide the fraction of each of four age cohorts (0-19, 20-39, 40-59, 60+) living in each of four house types (single-family detached, single-family attached, multifamily with five or more units per building, and mobile homes). Second, a projection of future population by state and by age cohort is multiplied by the fraction of those people who live in each house type to derive a projection of population in each house type in future years. Third, the number of persons per household by house type and by state is determined from the 1980 Census 0.1% sample. Fourth, the number of houses required of each type is obtained by dividing the number of persons in each house type by the persons per household appropriate for that state and house type. The number of persons per household in each state and housing type is assumed to remain constant over time at 2.76 persons per household (based on 1980 data). (Assuming declining persons per household produces inconsistency between the number of households required by the projected population and the projected number of new housing units. Accepting the projection of new construction requires rejection of either the population projection, the household projection, or the projected decline in persons per household.)

B.1.2.2 Housing Starts

The long-term projection of households, described above, is based on demographic trends, including changes in the age distribution of the population and projected decline in the number of persons per household. Because houses are added to the stock not only to accommodate population increases but also because of voluntary turnover or replacement of houses, projected population increases are only one factor in estimating housing starts for a fixed period. In addition, houses will be constructed to replace losses to the inventory. Economic factors, such as interest rates, will play a significant role in determining the actual number of houses constructed in future years. To account for economic factors, the LBL estimate of housing starts by state is scaled to agree with a recent projection of regional housing starts that includes economic factors.

B.1.3 Building Shell Thermal Integrity

The equation used in the Residential Energy Model to represent the thermal performance/cost tradeoff for structures is:

$$\frac{TIN}{TIN_0} = \frac{TINF}{TIN_0} + \left[\frac{TBETA}{TBETA + C} \right]^{TALFA} \left[1 - \frac{TINF}{TIN_0} \right] \quad (B.3)$$

where TIN is the thermal performance (relative heating energy normalized to 1980 existing houses); C is the change in the initial cost of the structure due to the change in TIN ; and $TINF$, $TALFA$, and $TBETA$ are parameters.

Table B.1 shows values of the parameters $TINF/TIN_0$, $TALFA$, and $TBETA$.

Table B.1 Parameters of Thermal Integrity/Cost Curves by House Type

	$TINF/TIN_0$	$TALFA$	$TBETA$
Single-Family	0.280	12	9600
Multifamily	0.434	4	1887
Mobile Homes	0.440	9	2291

The thermal integrity factor (TI) is the relative energy consumption corresponding to a set of building shell characteristics (e.g., ceiling insulation, floor insulation, glazing, floor insulation, infiltration rate), associated with an incremental cost (C). For space heating, it is calculated from the relationship each year to minimize the life-cycle cost, given current energy prices, using a discount rate consistent with historical market tradeoffs. The thermal integrity factor for air conditioning depends on, and differs from, the thermal integrity factor for heating.

Thermal integrity is largely irrelevant in the analysis of televisions, water heaters, pool heaters, and ranges and ovens. The only interaction between energy consumption of these products and the building shell characteristics is through internal loads generated by these products. Those internal loads interact with space-conditioning requirements.

B.1.4 Equipment Efficiency

The LBL-REM projects the average efficiency or unit energy consumption for a new unit purchased in each future year. The method involves characterization of historical market behavior, in the form of an implicit market discount rate. The observed average efficiency of the unit purchased is characterized as a function of the range of designs available from manufacturers, equipment prices (set by manufacturers and distributors), current residential fuel prices, and trade-off decisions made by purchasers (including homebuilders, contractors, landlords, and homeowners). The range of available designs and their prices are from the Engineering Analysis. Historical average efficiencies are reported by industry trade associations. Taking the average efficiency of units purchased as the minimum life-cycle cost defines the implicit market discount rate. The average efficiency in future years is projected based on the range of engineering designs available (characterized by unit price and efficiency) and projected residential energy prices, given the implicit market discount rate.

B.1.5 Market Shares

The number of potential purchasers is calculated for two markets: housing starts and potential replacement/retrofit in existing housing. Total product sales for each year are determined by applying market share elasticities to projected equipment price, operating expense, and income to determine the fraction of potential purchasers who will actually purchase the product. The market share elasticities include cross-price variables, where appropriate, to capture inter-fuel competition. (An example of inter-fuel competition is the choice between water heaters fueled by electricity or by natural gas).

The market share elasticities are constant over the projection period. The market share for each class in future years is described in Section 3.2 of Volume B through I.

B.1.6 Usage Behavior

The usage elasticities for televisions, water heaters, and pool heaters are assumed to be zero. Projected usage is assumed constant at the current values. The usage elasticities for room air conditioners, direct heating equipment, mobile home furnaces, and ranges and ovens are given in Appendix B of Volumes B through I.

B.1.7 Equipment Turnover

Tables 2.1 of Volumes B through I show average equipment lifetimes. These lifetimes are assumed to be constant over the projection period. The retirement functions (the percent of products which survives, as a function of years after purchase) are shown in Appendix B of Volumes B through I.

B.1.8 Outputs

The LBL-REM produces annual projections of:

- number of houses in stock by house type;
- housing starts by house type;
- thermal integrity factors for stock and new houses by house type;
- average unit energy consumption of new units sold (by class and by end use/fuel);
- average unit equipment price of new units sold (by class and by end use/fuel);
- fraction of existing houses having each end use;
- fraction of new houses having each end use;
- usage behavior factor, by end use/fuel;
- fuel consumption by housing type, by fuel, and total by end use;
- total equipment expenditures by end use; and
- total fuel expenditures.

The LBL-REM produces cumulative values for a period (1996-2030):

- fuel use by end use and fuel type;
- discounted fuel expenditures by end use and fuel type;
- discounted equipment expenditures; and
- discounted total (fuel and equipment) expenditures.

The LBL-REM produces cumulative values for new units purchased in a period (1996-2030):

- discounted fuel expenditures by end use and fuel type;
- discounted equipment expenditures by end use and fuel type;
- discounted total (fuel and equipment) expenditures by end use and fuel type;
- units installed by end use and fuel type; and
- total discounted life-cycle expenditures per unit by end use and fuel type.

Product types usually correspond to end uses.

B.1.9 Changes Since Previous Technical Support Document

The previous Technical Support Document was concerned with dishwashers, clotheswashers, and clothes dryers. (1) The principal changes since 1990 are:

- (1) The set of products being analyzed has changed.
- (2) The set of design options, efficiencies and cost data have changed (see Volumes B through I, Chapter 1).
- (3) Housing start projections have been revised downward, consistent with recent trends (see Volume A, Chapter 5).
- (4) Energy price projections have been updated (to *Annual Energy Outlook 1991*) (see Volume A, Chapter 5).
- (5) Equipment lifetimes have been re-estimated for water heaters, to distinguish among fuel types (see Volume F, Appendix B).
- (6) Initial stock and new market shares for space heating and cooling are revised, based upon 1987 *Residential Energy Consumption Survey*, industry shipments data, and (where applicable) revised equipment lifetimes (see Volumes H and I, Appendix B).

B.1.10 Input Data

The complete input listing is available on electronic medium in ASCII format. The input database includes demographic, economic, and engineering data. The input listing for products in the current proposed rule is reproduced in Appendix B in the respective volumes for each product.

B.2 COMMEND END-USE PLANNING SYSTEM

The COMMEND end-use planning system provides a framework for organizing and analyzing commercial-sector market data. COMMEND was developed by the Electric Power Research Institute (EPRI) for use by its member utilities. The main analysis uses are load forecasting for power system planning, demand side management planning, and market planning.

In recognition of the importance of the commercial buildings sector, EPRI initiated a research project (RP1216) in 1981 to develop and transfer end-use analysis tools, market information, and data-gathering strategies to the industry. At the core of this effort is the COMMEND framework, the COMMEND programs, and their supporting databases.

The COMMEND Framework. The COMMEND framework segments the commercial market by building type and end use. The framework is illustrated in Figure B-1. The detailed focus is driven naturally by emerging market issues and analysis needs.

The primary use of the COMMEND framework is long-term forecasting. However, the market databases that result from model implementation are vital inputs to a wide variety of planning and analysis activities.

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

The COMMEND Models. The COMMEND 2.0 model was a mainframe model, which has been distributed to over 80 utilities in the U.S. and abroad. COMMEND-PC 3.0 became available in 1988, and has been distributed to over 100 utilities in the U.S. and abroad.

In 1990, Version 3.1 became available. It contained minor changes to Version 3.0. Version 3.2 was released in April 1992.

COMMEND Data Bases. COMMEND-PC is distributed with a national data base, which is refined and updated as new information becomes available.

B.2.1 Discussion of the COMMEND Market Framework

The COMMEND model provides a conceptual framework for organizing market information. The purpose of the following discussion is to describe this framework, and to introduce the main analysis concepts. The focus is on the description of current energy-use patterns.

Market Segments

The purpose of segmenting a market is to group customers into segments with common properties. Across groups, the customers should have different product requirements or different market attitudes and preferences. Within groups, these requirements and attitudes should be more homogeneous.

The COMMEND framework uses a two-way primary segmentation scheme. The dimensions are building type and end use.

Building-Type Segments. Building types define the primary market segments. This approach is useful because energy-use patterns differ strongly across building types. These differences reflect:

- Different operating hours,
- Different types of energy-using activities,
- Different types of energy-using equipment, and
- Different energy-using technologies.

The building type has great intuitive appeal. For example, we all know what a high-rise office building looks like, and we are unlikely to confuse it with a fast-food restaurant. Further, the linkage with energy-use patterns is clear. Offices have different operating hours and house a different mixture of energy-using equipment than do restaurants, hospitals, or warehouses.

However, there are ambiguities that arise in applying the building type concept. Much of this derives from the following facts:

The term *building type* refers to the use of the internal space as well as the characteristics of the structure itself. Further, the use may change over time or a single structure may have mixed uses at a point in time.

Reflecting these facts, many analysts refer to the segments as building/activity types.

End-Use Segments. An energy end use is the ultimate service delivered by energy-using equipment. In COMMEND 3.2 the end-use categories are:

- Space heat
- Cooling
- Ventilation
- Water heating
- Cooking
- Refrigeration
- Exterior lighting
- Interior lighting
- Office equipment
- Miscellaneous.

These segments are defined in terms of the final service being provided by energy inputs. Within each end-use segment, these classes of decisions will impact the type of fuel and the level of energy use:

- **Fuel choice** refers to decisions among alternative equipment that provide the same service but use different types of fuel. The main competitive uses are heating and cooling and the main fuels are electricity, natural gas, and fuel oil.
- **Efficiency** decisions refer to decisions about equipment features and structure features that determine how much energy is required to deliver a given level of end-use service.
- **Utilization** refers to the frequency and duration of equipment usage. This is impacted by occupant behavior and equipment operating controls.

Typically, all of the end-use segments appear in each of the building types. For example, space conditioning and lighting are important end uses in all building categories. Others, such as cooking and refrigeration, are more concentrated in particular building types.

From the perspective of the equipment producers and distributors, the end-use segments are separate markets. For example, heating, ventilation, and air conditioning (HVAC) equipment manufacturers do not view lighting appliance manufacturers as competitors. This perspective could also be adopted here, in which case we would refer to the heating market rather than the heating segment of the commercial energy market.

Other Segments. The COMMEND framework also tracts buildings according to the year of construction, referred to as the *building vintage*. This allows fuel and efficiency decisions to be analyzed separately for new construction versus retrofits and replacements.

In many applications, building types are further split on the basis of size. The most common example of this is the separate treatment of large versus small office buildings. This separate treatment is prompted by the fact that large buildings have different thermal properties and tend to utilize different types of HVAC technologies than do smaller buildings.

Central Energy Equation

The COMMEND framework provides an analysis structure for describing energy-use patterns. The primitive concepts in the framework are as follows:

- Floor stock (square feet of building space),
- Energy intensity (energy per square foot),
- Fuel share (percent of area served by an end use and fuel type),
- Energy-use index (energy per square foot for an end use),
- Peak-day fractions (share of annual energy), and
- End-use load profiles.

These are the key concepts used in commercial-sector energy analysis. By developing data for these concepts, a complete profile of the commercial sector can be produced.

For each market segment, the central *energy equation* in COMMEND defines current energy use as the produce of three factors. These are floor stock, fuel share, and energy use index (EUI). For a single building/end-use segment, the central equation is:

$$\text{Annual Energy Use} = \text{EUI} * S * F \quad (\text{B.4})$$

where:

F is square footage of floor stock,
S is average share of space served by the end use and fuel, and
EUI is average energy use for served space.

In this definition, the floor is the total amount across all building vintages, and the share of EUI values are average across buildings of all vintages. As an average, the EUI value embodies both average equipment efficiencies and average usage levels across the customer base in the segment.

As an example of this equation:

- Fifty million square feet of office space
- With 25% electric space heated, and
- An electric heating EUI value of 10 kWh/foot/year, gives
- Annual energy use of 125 gWh (50 million feet * .25 * 10 kWh/foot).

The central energy equation is a definition of energy use. Other definitions are possible and are sometimes used. For example, one alternative is to use employment times energy use per employee. Another is to use a measure of output times energy per use unit of output. These alternative definitions are valid, but for the commercial sector have not proven as useful as the floor stock approach.

Floor Stock. *Floor Stock* provides the basis for energy-using equipment and activities in the commercial sector. In new construction, energy-using technologies are an integral part of building design. In fast-growth areas with high construction levels, many energy equipment decisions are being made and new technologies can penetrate the market rapidly. In slow-growing areas, relatively few equipment decisions are made, and they are restricted to replacement and retrofit in the existing stock.

Energy Intensity. The term *energy intensity* applies to total energy use per square foot for all end uses. For example:

- A typical office building intensity of 18 kWh/foot for electricity and 45 kBtu/foot for natural gas.
- A typical restaurant intensity is 36 kWh/foot for electricity and 140 kBtu/foot for natural gas.

The numerator in these intensity ratios is annual energy use. The denominator is total square footage.

Trends in energy intensities reflect changes in fuel shares, changes in equipment efficiencies, and changes in usage levels. At a point in time, the efficiency and usage factors are captured by the average EUI value.

Fuel Shares. *Fuel shares* indicate the share of building space that is served by a particular end use and fuel type. The term is used to indicate both stock and flow concepts.

- The stock concept refers to the share of all buildings existing at a point in time. This is sometimes referred to as a penetration or market saturation. We call this the *average share*.
- The flow concept refers to the share of current decisions in new construction and replacements. This corresponds more closely to an equipment supplier's concept of the share of current shipments. We call this the *marginal share*.

The share concept used in COMMEND is applied to total floor stock rather than the penetrated portion of the stock. For example, if 90% of floor space is in buildings with heating, the shares will add up to 90% across fuels.

Two types of share definitions are commonly used. The first is the "whole-building" approach. This approach measures shares of space in buildings with an end use regardless of the portion of each building that is served or conditioned by the end use. The second is the "conditioned-space" approach, which accounts for the fraction of each building that is conditioned by the end use.

Energy Use Index (EUI). The term *energy use intensity* refers to a measure of average annual energy use per square foot of floor space in buildings that are served by an end use.

In the residential sector, a similar concept is used, called unit energy consumption, or UEC. This measures annual energy use by an average household appliance unit. This approach is not suitable for the commercial sector due to the wide range of building sizes and equipment types that are used in these buildings. By focusing on a typical square foot, the EUI is a standardized concept.

EUI values embody an average level of service and average equipment efficiency. There are several options for units of measurement. The standard approach is to develop electric values in kWh/foot and fossil fuel values in kBtu/foot.

For each end use, EUI values will differ across building types and across fuels. For example, for space heating in offices, suppose that:

- The electric EUI is 20 kBtu/foot (about 6 kWh/foot) and
- The gas EUI is 50 kBtu/foot.

This difference in EUI values across fuels reflects differences in equipment efficiencies, in the thermal features of buildings using gas and electricity, and in usage levels. Differences in usage levels may reflect fuel price differences as well as technology-related factors.

Usage Levels. *Usage level* is the most difficult of the COMMEND concepts to quantify. Ideally, it would be measured in terms of energy services delivered. Examples are:

- Delivered heat in Btu for space heating
- Heat removed in tons for air conditioning
- Lighting delivered in lumen hours.

Given these measures, usage is determined by occupant behavior, equipment controls, and other factors. Usage levels would change, for example, if thermostat settings are changed, comfort levels are altered, lighting fixtures are changed, or operating hours are altered.

Load Shapes

The discussion thus far has focused on annual energy use. The COMMEND framework also deals with daily energy use and with peak-day load shapes. The approach used relies on fixed fractions.

The first set of fractions indicates the share of annual energy use that occurs on the winter and summer peak days. These are referred to as *peak-day fractions*. The second set of fractions contains load profiles for each electric end use. These fractions are used to spread annual energy use from the daily total to hours of the day. Combined, these values allow the translation of annual energy usage levels to peak-day loads.

Example of Market Profiles

The market data described above represent a COMMEND data base. Figure B.2 provides an illustration of the types of results that can be obtained from a COMMEND implementation. The data presented here reflect actual results that have been developed from the COMMEND 3.1 national data base. These data have been scaled down to reflect about 1% of the U.S. total.

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

B.2.2 COMMEND Forecasting Framework

For the base year, the market profiles discussed above provide a detailed depiction of energy-use patterns at the end-use level. The purpose of the COMMEND forecasting framework is to project these detailed profiles into the future.

By forecasting at the end-use level, it is possible to isolate the influences on energy sales of economic growth, changes in fuel shares, changes in efficiencies, and changes in usage levels. This approach allows consideration of key issues in future markets, such as fuel competition, technology competition, building standards, and customer behavior.

Central Energy Equation

As discussed above, end uses within building types are referred to as market segments. The COMMEND forecast framework applies separately to each segment. As a result, it is appropriate to think of COMMEND as a matrix of models, as depicted in Figure B.3.

Figure B.3 COMMEND Framework for Long-Term Forecasting

Within each market segment or model cell, COMMEND computes energy sales using the *central energy equation*. This equation sums across all building vintages as follows:

$$\text{Sales}_t = R U_{fv} * E_{fv} * S_{fv} * F_v \quad (\text{B.5})$$

This equation defines annual energy sales for each fuel (f) as the sum across vintages (v) of the product of four factors. Starting from the right-hand end, these factors are:

- *Floor stock* of vintage v (F_v),
- The *share* of vintage v space using fuel f equipment (S_{fv}),
- EUI for fuel f equipment in vintage v space (E_{fv}), and
- Utilization rate for fuel f equipment in vintage space (U_{fv}).

This definition holds in each forecast year for each fuel.

All end-use models use this type of definition as a starting point. The definition is not a static one, since each of the model components will change over time. These changes reflect economic decisions in the commercial market, such as the decision to build, the choice of

construction materials, the type of energy-using equipment to install, and the eventual usage pattern of this equipment. The challenge in end-use modeling is to provide an abstract model that captures the main influences on these decisions and that projects over time the basic trends in each component.

COMMEND's general framework is presented in Figure B.4. The remainder of this discussion focuses on Version 3.2 and briefly describes each model component, forecast logic, and forecast results.

Figure B.4 COMMEND Forecast Framework

Floor Stock

The floor stock component of COMMEND is used to organize information about the existing floor stock and to forecast future stock levels. The floor stock outlook embodies the utility planning assumptions about growth in economic activity for the commercial sector. This outlook will be tightly linked to population growth, employment growth, and regional income.

Data about historical stock is input to the model. The key input values are:

- *Base year floor stock* (e.g., 1987).
- *A historical floor stock series* from a distant year to the base year (e.g., from 1941 to 1987). This series can be developed in the model using historical additions, scale variables (such as employment or population), or a combination.
- *Survival functions* describing building survival and decay over time.

A flexible forecasting framework is provided. Two general approaches can be used.

- In the *flow approach*, annual building construction is projected directly. The stock is inferred as the old stock, having survived for one or more years, plus the new additions.
- In the *stock approach*, the final stock is projected directly. Additions are inferred as the amount of construction required to produce the projected stock value.

With either approach, the user provides forecasting equations, including estimated coefficients and exogenous variable forecasts. Typically, the exogenous variables come directly from a service territory economic model. Variables that are used are (1) employment in the economic SIC codes, (2) population by age group, (3) regional income, and (4) construction industry conditions, such as interest rates. Within this general framework, simple and complex forecast approaches can be implemented.

Modeling Share, EUI, and Usage Decisions

The remaining three items in the central energy equation are fuel share, EUI values, and usage levels. Fuel shares and EUI values both reflect the outcome of choices among energy technologies. These choices are investment decisions made by building owners, designers, and contractors at the time of construction or equipment replacement. Decisions involved include:

- The decision to use a *generic technology* (such as an electric heat pump or a gas furnace). This determines the fuel share for each fuel.
- The decision to select a *specific technology* (an equipment brand and model), along with structure characteristics and initial usage patterns. This determines the EUI for each fuel.

Once a building is constructed and equipment is in place, changes in usage levels reflect daily decisions about the frequency and intensity of equipment use. These decisions are determined by the behavior of building managers and occupants.

A variety of approaches have been used to model these decisions. The focus of these approaches is on the impact of fuel prices on market decisions. These impacts are:

- **Fuel Choice.** An increase in one fuel price may cause switching away from that fuel to other fuels. For example, an increase in electric prices will cause a switch to fossil fuels. An increase in gas prices will cause a switch to electric technologies.
- **Technology Choice.** An increase in a fuel price may cause switching to more efficient technologies. This can involve either more efficient equipment models or the addition of energy-conserving features.

- **Usage Behavior.** An increase in a fuel price may cause a reduction in the usage level through changes in the behavior of building occupants. Examples are reduced lighting level and more conservative thermostat settings.

COMMEND 3.2 uses a probabilistic choice approach for fuel and efficiency choice. In this application, the model outcome is the probability that a specific system is installed in a particular building. The probability will depend on the following:

- The capital cost of all system options,
- The operating costs of all system options, and
- Characteristics of the building and other relevant factors.

The probabilistic approach is appealing because it is not possible to observe all the factors that affect equipment decisions. Therefore, it is not possible to predict these decisions perfectly. This philosophy contrasts with the life-cycle cost (LCC) minimization approach, which posits that each choice is known precisely, based on a complete set of cost information and pure economic optimization.

The probability approach does not have the knife's edge property associated with LCC minimization. For example, a change in fuel prices alters operating costs, which in turn reorients the probabilities. These shifts will be sudden and dramatic only if estimated parameters suggest a high sensitivity to operating costs.

Key inputs to the modeling process are grouped into technology data, economic data, and standards and DSM data. These are described below.

Technology Data. Technology data center on equipment costs and efficiencies. The main technology inputs are:

- **Heat Pump Data.** Heat pump shares and relative efficiencies are needed to unbundle the overall electric heating EUI and share into resistance and heat pump components.
- **Equipment Costs.** Average installed system costs for all end uses by building type are entered in \$/square foot.
- **Efficiency Ranges.** For each generic technology, the range of available suboptions is described. The range for each system is described as a curve segment. Parameters of the segment are EUI range percentages and a tradeoff elasticity between outlay and energy use. The implied cost range is computed internally. This is referred to as the generic technology curve approach. These data describe the opportunity for price-induced efficiency changes.
- **Efficiency and Costs Trends.** For each generic technology, trend values that alter equipment efficiencies and installed costs may be specified. These impacts can be used to evaluate the impacts of naturally-occurring technology improvements.

- **Thermal Interactions.** Thermal interaction elasticities are used to describe the impact of changes in lighting and miscellaneous loads on HVAC energy use. Separate parameters give the impact of changes in building thermal characteristics on HVAC energy use.

The equipment cost data determine the relationship between capital costs and operating costs, which is important in determining the importance of energy prices in equipment decisions.

Economic Data. The economic data describe decision-makers and decision rules. These data are defined as follows:

- **Decision-Maker Data.** Decision-makers are described by a block distribution of *discount rates*. These distributions may differ across building types. The decision-makers have *price expectations* which are based on a single distributed lag adjustment mechanism. This implies that price expectations are formed on the basis of past price events.
- **Efficiency Option Elasticities.** These parameters give the sensitivity of market shares to life-cycle cost, where life-cycle cost includes both initial equipment cost and the present value of operating costs. These sensitivities are used to model efficiency choice for all end uses.
- **Share Option Elasticities.** Like the efficiency option elasticities, these parameters give the sensitivity of market shares to life-cycle cost, where life-cycle cost includes both initial equipment cost and the present value of operating costs. These sensitivities are to model market shares of competing fuels and technologies.
- **Automatic Calibration.** The technology data and decision data are combined to compute implied efficiency elasticities and to calibrate fuel-choice equations. These equations are calibrated to marginal shares in new construction.
- **Utilization Elasticities.** These parameters indicate the sensitivity of equipment usage to energy prices, as well as weather data, operating hours, vacancy rates and other factors. These parameters are used to simulate changes in usage levels over time.
- **Replacement Factors.** Fuel share inertial parameters apply to fuel choice decisions in appliance replacement. They reflect the presence of barriers to fuel conversion when equipment is replaced. EUI inertial factors apply to efficiency changes at the time of equipment replacement.
- **Office Equipment and Miscellaneous Equipment EUI Growth.** These parameters allow office equipment and miscellaneous equipment EUIs to grow independently for each building type in the forecast period.

Standards and DSM Data. This section includes data related to equipment efficiency standards, thermal efficiency standards and DSM program impacts. These inputs are described briefly below.

- **Efficiency Standards.** This section contains data that identify the timing of efficiency standards and that describe the impact of these standards on (1) equipment efficiency ranges and (2) the level of thermal efficiency in new construction.
- **Efficiency Incentives.** This section allows introduction of incentive or rebate payments for equipment that meets specific efficiency requirements.
- **Specific DSM Program Impacts.** This section allows imposition of DSM program impacts by building type, and end use and fuel.
- **General DSM Program Impacts.** This section allows imposition of impacts by building and fuel. Specific end uses are not identified.

Forecast Logic

Given the model parameters, the key steps in the forecast logic are summarized as follows:

- Compute price forecast,
- Compute floor stock forecast,
- Compute efficiency/cost changes,
- Trends and standards move curves,
- Simulated elasticities give changes along curves,
- Compute share changes,
- Compute replacement impacts,
- Shares,
- Average EUIs,
- Compute utilization impacts, and
- Apply central energy equation.

Forecast Results

COMMEND 3.2 forecast results are summarized below.

- Price forecast,
- Floor stock forecast,
- Energy sales forecast,
- Sales forecast by building type,
- Sales forecast by end use,
- Summer peak demand forecast, and
- Winter peak demand forecast.

Figure B.5 presents an example of forecast results using the COMMEND 3.1 national data base.

Figure B.5 Forecast of Electricity Sales by End Use (gWh) (1% of U.S. Total)

APPENDIX C. LBL MANUFACTURER IMPACT MODEL

C.1 OVERVIEW OF MANUFACTURER IMPACT MODEL

C.1.1 Purpose

The Lawrence Berkeley Laboratory Manufacturer Impact Model (LBL-MIM) collects into one spreadsheet all the calculations necessary to determine the impact of a change in appliance efficiency standards on an industry's profitability and scale of operation. The spreadsheet design makes it possible to quickly analyze the effects of uncertainties in input values and to efficiently incorporate new data into the calculations. The model has a control panel, which makes the analysis of uncertainty particularly straightforward for nine of the model's crucial inputs. Through this panel, the model provides the user not only with the best estimates of financial impacts, but also with the uncertainty of these estimates and a sensitivity analysis attributing that uncertainty to certain input variables.

C.1.2 The Economic Approach

The impact of efficiency standards on manufacturers depend on the interaction of three factors: (1) the costs imposed by the change in standards, (2) the price elasticity of a single typical firm, and (3) the industry's price and operating cost elasticities of demand. The LBL-MIM integrates and analyzes these four factors as they apply to a single typical firm.

A change in standards will generally create three types of costs for a firm. First, variable costs of goods sold (VCGS) will be affected by new parts and labor requirements. Second, some engineering will be required to design, test, and plan the manufacturing of new products. And third, new products will require re-tooling and new equipment (capital) costs. The incorporation of VCGS is straightforward, but engineering and capital costs must be amortized to be converted from one-time costs to annual costs for a typical-year model.

Markups from manufacturing costs to ex-factory prices depend on the single-firm price elasticity. Because it is difficult to find data on single-firm price elasticities, the LBL-MIM infers them from the firm's fixed costs and return on equity (ROE). The markup is over variable cost and not fixed; hence it must be greater than one if a firm with fixed costs is to recover its fixed costs and turn a profit.

The industry has two elasticities of interest: its price elasticity and its operating cost elasticity. Although individual firms must calculate according to their own elasticities of demand, it is ultimately the industry elasticities that determine the level of demand experienced by each firm. This apparent paradox arises because the model assumes that all firms are profit maximizers and thus respond in essentially the same way to the imposition of standards. Because of this

assumption, all firms change the prices and operating costs of their appliances by the same amount (i.e., the industry acts in unison). When this happens, sales for each firm are determined by the industry elasticities.

C.1.3 Measures of Impact

The LBL-MIM computes two primary and several secondary measures of impact. The two primary measures, ROE and net income, are both necessary because they can move in opposite directions. For instance, if net income increases, but assets and thus equity increase by a greater percentage, ROE will decline. If the decline is large, the net effect will be viewed as negative, but if a small decrease in a healthy ROE is accompanied by a large increase in net income, the net effect might be viewed as positive.

In addition to ROE, return on assets and gross margin are also computed. Other outputs are total assets, shipments, revenues, and average price; these help explain the origins of changes in the primary inputs.

C.1.4 Methodology

How standards are implemented in the model

Generally, a change in standards affects the model in three distinct ways. Standards require additional investment, raise production costs, and affect revenue.

The most obvious investment induced by standards is the purchase of new plants and equipment. This cost is first evaluated from engineering data, and then amortized by taking into account the life of the investment, the timing of the expenditures, tax laws, and the cost of funds. An additional (and sometimes larger) investment is made as the old inventory is replaced with more expensive new units. The model assumes that previous inventory ratios are maintained. A third form of investment tracked by LBL-MIM is the change in the transactions demand for cash that accompanies a change in revenues.

Increased costs of production are modeled by coupling changes in unit costs with changes in product shipments. Changes in unit costs come from engineering data and shipments data come from LBL-REM.

Revenue is affected both by price and shipments. Price is determined by computing the markup over long-run marginal costs, and then using the markup to determine an optimal price. Shipments (demand) is determined by price and operating cost elasticities, coupled with the changes in price and operating costs resulting from the standards.

Revenues (R) and costs (C)

Figure C.1 Profit Maximization and Fixed Costs

Typical-year approach

The LBL-MIM uses a typical-year approach rather than a dynamic approach. This approach models a "typical year" for the industry both in the base case and in the new standards case. The year chosen for the model is the fourth year after the imposition of standards, and is selected because it is believed to be long enough to capture any major impacts from the standard, such as profitability changes or firm entry into or exit from the industry.

Use of prototypical firms

Because the engineering and financial data for most firms are proprietary, LBL-MIM models a prototypical firm. In many cases, this firm must be thought of as representing an autonomous division of a larger firm. A prototypical firm is a hypothetical firm that is representative of the industry. Prototypical firms are defined by parameters that are important for determining the impacts of standards and are consistent with data for the portion of the industry they represent. Important parameters used in the model include the cost structure of the firms, profitability ratios, relative costs of complying with the new standard, and marketing strategies.

Product segmentation

The LBL-MIM assumes that the product market is segmented. Thus, different products have different markups. In general, it is found that appliance manufacturers are able to charge different markups for products that have different characteristics. They can charge higher markups on products that have desirable characteristics, such as water heaters with heat pumps or color TVs with remote control. Products without such desirable features are generally bought in larger quantities at lower prices by consumers who are more price-conscious, and thus the markups for these products are lower. The per-unit profits made by manufacturers for these different products may differ significantly.

C.2 STRUCTURE OF THE LBL-MIM

C.2.1 Economic Theory and Assumptions

The basic question that LBL-MIM must answer is: how much of the cost increases caused by standards can be passed through to consumers? If less than the normal pass-through occurs, profits will suffer, while an above normal pass-through will increase profits. To answer this question precisely, it is necessary to compute a markup; but, before that, a more intuitive understanding of the relevant economics will be useful.

Economists often divide cost into fixed and marginal components; fixed costs are just what their name suggests, and marginal costs are the costs of producing an additional unit of output. Three facts are true in general of these cost distinctions:

1. Under perfect competition, price equals marginal cost.
2. Under imperfect competition, i.e., with a downward-sloping demand curve, price equals marginal cost times a markup.
3. In neither case do fixed costs enter the calculation of price.¹³

The first point may be understood by assuming for a moment that it is false and that price is higher. In this case, each firm would think it profitable to produce more (since in perfect competition each knows that as an individual firm it can have no effect on price), which would certainly drive prices down. The reverse argument holds with price below marginal cost, so, in either case, price will inevitably change to equal marginal cost. The second fact is derived in the next section. The third point is most easily understood by examining Figure C.1, which shows a revenue curve and two total-cost curves that differ only in their fixed components.

How will a firm respond to an increase in fixed cost (represented by the upward shift displayed in the cost curve)? Since the firm wishes to maximize the difference between cost and revenue, it chooses the optimal output Q^* . This choice is clearly independent of the shift in fixed cost, but once output is determined, the demand curve will dictate the price at which that output can be sold. A change in fixed cost has no effect on the demand curve and thus no effect on price.

The separation of costs into fixed and variable must be done with an eye to the time horizon under consideration, because many (if not most) costs that are fixed in the short run become variable in the long run. Three distinct time horizons are useful: the short run, the long run, and the very long run. In the short run, the productive capacity of the firms in the industry remains fixed. In the long run, capacity may be adjusted, but the number of firms remains constant. In the very long run, firms may enter or leave the industry, with the result that an individual firm's market power, as measured by its price elasticity of demand, may change. Thus, in the very long run, markup may change.

In the long run, price is a markup over long-run marginal cost, while in the short run, price is a markup over short-run marginal cost. Since in the long run, but not in the short run, capital is considered a marginal cost, how can the two pricing rules be reconciled? If a firm finds that its long-run plans have been realized (in other words, if the market conditions are those that it foresaw at the time it planned its present capacity), then long- and short-run marginal costs

¹³Two interpretations may legitimately be given to this mathematical result. First, one may say that given the demand function, marginal cost determines price and fixed costs are not passed on. Alternatively, one may argue that fixed costs indirectly determine the elasticity of demand, and thereby the markup over marginal cost. Thus (indirectly) fixed costs are passed on through the markup of marginal cost. The mechanism providing this indirect link is the following: if fixed costs are not covered, then economic profits will be negative and some firms will leave the industry; this will reduce competition and thus reduce each firm's elasticity of demand. Conversely, if fixed costs are more than covered, positive economic profits will induce entry and elasticity and markup over marginal cost will be reduced.

will be equal. This is possible because although capital is not included as a short-run cost, other costs are short-run but not long-run costs. These are the costs associated with an increase in output beyond the planned long-run capacity level. If a plant is running optimally, output has been pushed to the point that short-run marginal costs equal long-run marginal costs; otherwise a different size plant would have been more profitable.

The next section gives an overview of the LBL-MIM from a theoretical perspective, after which some results of central importance are derived and their application to the long-run model is reviewed. Finally, the short-run part of the model is discussed.

Theory and the LBL-MIM

From our discussions with the industries involved and industry consultants, we know that there are fixed costs (i.e., unit cost decreases as quantity decreases) in the production of the appliances analyzed. Consequently, each producing firm must not face an infinite elasticity of demand because a small increase in price charged will not result in a 100% loss of sales due to induced entry of competitors. As a result, we know that the appliance-manufacturing industry is not perfectly competitive and thus, the LBL-MIM models typical firms as having a combination of fixed and variable costs, and as facing a demand curve with finite elasticity.

The next section derives the equations relating markup, fixed costs, variable cost, and economic profit. These relationships have been a standard part of economics for many years, hence these derivations are included for the convenience of the reader and not as an explanation of theoretical results new to this study. One exception to this disclaimer is the discussion on oligopsony power and the "effective" number of firms. There is no generally accepted theory on how to model a market characterized by significant market concentration on both the seller's and the buyer's side. As a result, we discuss our approach in greater detail below.

Derivation of markup

To begin the derivation of the markup equation, assume that firms maximize economic profit, where economic profit is revenue minus economic cost, and economic cost includes the cost of equity and all taxes. Economic costs (C) are assumed to be linear functions of output (Q) and revenues (R):

$$C = b_0 + b_1Q \quad (C.1)$$

Although cost is written as a linear function of output, this is not essential; a non-linear cost function would give a mathematically equivalent, but more difficult to express, result.¹⁴

Next, make the standard economics assumption that firms maximize economic profit ($R-C$). Since the cost of capital is included in economic cost, a firm with an ROE equal to the cost of capital will find its economic profit to be zero. If, however, a firm can earn a higher ROE, it is assumed that it will, in which case $R-C$ will be positive. The firm can maximize profit by picking either a quantity to produce (Q) or, equivalently, a price to sell it at, but it cannot choose both. The following computations assume that profit is maximized with respect to Q . This gives the following first-order condition:

$$\frac{d}{dQ}(R-C)=0 \quad (C.2)$$

This equation completes the description of the supply-side assumptions. The demand side is described by an elasticity of demand which may vary, but which at the market equilibrium takes the value e . Elasticity of demand is the percentage change in demand caused by a 1% change in price P , and consequently is negative. Mathematically, this is expressed as follows:

$$\frac{dQ}{dP} \cdot \frac{P}{Q} = e \quad (C.3)$$

All necessary assumptions have now been made, so all that remains are some mathematical manipulations. From the two supply assumptions, and denoting dR / dQ by R' and dP / dQ by P' , we have:

$$\frac{d}{dQ} [R - bt_0 - bt_1Q] = 0 \quad (C.4)$$

¹⁴ If we assume that cost is an arbitrary function of Q , $C(Q,R)$, our final result, will differ only in that the two types of cost (bt_0 and bt_1) will be replaced by $C - Q(dC/dQ)$ and dC/dR , respectively.

By definition:

$$R' = \beta_1 \quad (C.5)$$

$$R = P \cdot Q \quad (C.6)$$

$$R' = \frac{P}{\frac{dQ}{dP} \cdot \frac{P}{Q}} + P \quad (C.7)$$

$$\rightarrow R' = P' \cdot Q + P \quad (C.8)$$

$$R' = \frac{P}{e} + P \quad (C.9)$$

$$R' = \frac{P}{e} + P \quad (C.10)$$

$$P = \frac{e}{1+e} \text{bt1} \quad (C.11)$$

In this last equation, price is a simple markup over marginal cost and may be found in any standard text on industrial organization. Now we define the markup:

$$\mu = \frac{e}{1+e} \quad (C.12)$$

Note that because the own-price elasticity (e) is negative, μ is greater than 1. Of course if $e \leq -1$, then μ is undefined, since the firm makes more the less it sells.

A small rearrangement of Eq. C.12 provides a simpler look at the markup equation:

$$P = \mu b t_1 \quad (C.13)$$

Price formation can be explained as follows: marginal costs are marked up by both μ and fixed costs are not passed on at all.

It is now easy to derive another representation of μ which is used in the calibration stage of the LBL-MIM to estimate μ from Eq. C.1:

$$(R-C) = R - b t_0 - b t_1 \cdot Q \quad (C.14)$$

Using Eq. C.5:

$$R = P \cdot Q = \mu b t_1 Q \quad (C.15)$$

so

$$(R-C) = \mu b t_1 Q - b t_0 - b t_1 Q \quad (C.16)$$

and

$$(R-C) = (\mu - 1) b t_1 Q - b t_0 \quad (C.17)$$

Finally,

$$\mu = 1 + \frac{(R-C) + b t_0}{b t_1 Q} \quad (C.18)$$

This equation shows that markup is economic income ($R-C$) plus fixed costs, all over total variable cost. The calibration calculations of the long-run module uses a simple variation of this equation in which bt/Q is replaced by $C-bt_0$, and the relation, $R-C = EP$, where EP is economic profit, is used twice. The new form of the equation is:

$$\mu = 1 + \frac{EP + bt_0}{R - EP - bt_0} \quad (C.19)$$

Markup is determined by revenue, economic profit, and fixed costs. Generally, it has been found that fixed costs are large relative to economic profit, so the numerator is controlled largely by the fixed cost. Thus, markup is primarily determined by the size of fixed cost relative to revenue.

Oligopsony Power and the "Effective Number of Firms

From an evaluation of the analyzed industries (see Chapter 4, Industry Profile), we see that the market structures of the industries are oligopolies and model them accordingly. However, the situation is further complicated by the fact that the demand side of the market is also heavily concentrated due to the presence of large retailers who have a great deal of market power.¹⁵ In other words, we have an oligopoly facing an oligopsony. Consequently, the standard oligopoly model needs to be modified. Unfortunately, there is no standard theory on how to model an industry with such a market structure. After examining the evidence of oligopsony, an outline will be made to show how we incorporate this into the model.

The rise of large retailers in the home appliance industry is a relatively recent phenomenon. They are generally defined as multi-market large-volume retailers, which includes firms such as Sears, Montgomery Ward, Circuit City, and Highland. For example, the home appliance retail share of Sears and Montgomery Ward alone has been estimated to be about 30% for various products. One indication of this oligopsony power is that if theoretical markups based on the actual number of firms in the industry are estimated, we find that the markups are much too large relative to what we observe in the market.

We address both the problems of oligopsony and of "over-estimated" markups by assuming that the low observed markup is the result of oligopsony power, and is an indication of the strength of that power. Since a firm's markup is directly related to the elasticity of the

¹⁵The increasing concentration on the demand side of the market also agrees with comments by the home appliance industry during the comment for these and other appliances. For instance, see AHAM, "State of the AHAM to the Department of Energy on Notice of Proposed Rulemaking on Energy Efficiency Standards for Clothes Dishwashers, Clothes Washers and Clothes Dryers," CE-RM-88-101, October 10, 1989.

demand it faces, we can find the single-firm demand elasticity that corresponds to the observed markup. This same elasticity is also implied by the industry elasticity and a Cournot oligopoly with some hypothetical number of firms. This allows us to compute the hypothetical or what we refer to as the "effective" number of firms from the observed markup. We then model the industry as if it were a Cournot oligopoly facing a competitive, not oligopolistic, demand for its product, but we use the "effective" number of firms rather than the actual number of firms to reflect the impact of the oligopsony. The effect of this is to reduce the market power of the individual firm to agree with our observation of markup. Although the reduced market power is a consequence of specifying too many firms, and not of modeling oligopsony, we believe that it provides a good first-order approximation to the actual market structure and provides a way around the intractable problem of modeling a market with imperfectly competitive demand and supply sides.

We now show how markup is computed from economic profit and fixed costs, and how the "effective" number of firms is computed from markup and industry demand elasticity. A well-known result for a Cournot oligopoly is:

$$e = NF * e_i \quad (C.20)$$

where:

$$\begin{aligned} e &= \text{the firm elasticity of demand,} \\ e_i &= \text{the industry elasticity of demand, and} \\ NF &= \text{number of firms.} \end{aligned}$$

We can solve for NF if the two elasticities are known. We have an estimate of e_i , and can estimate e as follows. From Eq. C.5, we know that:

$$e = \frac{\mu}{1-\mu} \quad (C.21)$$

Thus, we can find the markup, μ , in Eq. C.21 from Eq. C.4, if we know marginal cost c . Marginal cost can be found from the firm's return on equity, its fixed costs, and the following price identity: $\pi/Q = P - c + FC/Q$, where FC is fixed cost. This is just a restatement of the definition of economic profit, which is revenue minus costs. Noting that revenue, R , equals $P * Q$, we have:

$$\mu = \frac{P}{c} = \frac{P}{P - \frac{FC}{Q} - \frac{\pi}{Q}} = \frac{R}{R - FC - \Pi} \quad (C.22)$$

This gives a formula for markup μ based on our most easily observed variables. Solving Eqs. C.9 and C.10 for e , we can now find the number of firms, NF :

$$NF = \frac{\mu}{e_i \cdot (1 - \mu)} \quad (C.23)$$

We find that given two elasticities estimated from actual data, NF is higher than the actual number of firms observed.

To summarize, we first look at a typical firm's profit and fixed costs. In order to recover fixed costs, a firm must mark up over variable costs, and if it can mark up enough, it will make above "normal" ROE. From these considerations, we find its markup. The markup indicates a firm's industry demand elasticity and the effective number of firms in the industry. We use it in subsequent calculations.

The base case: 1990 NAECA standards

In the *long-run model module*, the calibration case is immediately followed by long-run calculations for the state of the industry in 1996 provided that the 1990 NAECA standards are unmodified. These calculations use the markup that is based on the one just calculated and modified in keeping with the assumption that demand elasticity with respect to life-cycle cost is constant. The modified markup is calculated as in Eq. C.5 but from a modified price elasticity. The new price elasticity is obtained as follows. First, the original price and operating cost elasticities are used to determine a life-cycle cost and an elasticity with respect to that cost. A demand curve with constant life-cycle cost elasticity is then computed. It takes this form:

$$Q = a \cdot (P + ff \cdot F)^B \quad (C.24)$$

where P is price, F is operating (fuel) cost, ff is the fuel-cost factor, and B is the elasticity with respect to life-cycle cost. Then price and fuel cost are changed from the calibration case to either the base case or a long run case. These changes shift the division of demand elasticity between the price and operating cost. In particular, the price elasticity is given by:

$$e = \frac{B \cdot P}{P + ff \cdot F} \quad (C.25)$$

As price increases as a fraction of life-cycle cost, the price elasticity increases.

The added costs to meet standards are divided into two categories: capital, and parts and labor. Capital costs come in two varieties, tooling and equipment. These are not currently separated by the model because we do not have separate data from the manufacturers. Since the chief economic difference between these two is their expected life, the LBL-MIM, in its amortization procedure, uses an intermediate value for the lifetime of new capital. This procedure takes a one-time capital expense and converts it to an annual expense, taking into account the cost of debt and equity, the tax laws, the lifetime of the capital, and the age of any capital being replaced.

Once the cost of capital has been annualized, it must be divided into fixed and variable parts. The fixed part is then added to *bt0*, while the remainder is divided by *Q* and added to *bt1*.

Since there are undoubtedly some economies of scale when parts are purchased, the LBL-MIM provides for a division of the cost of parts and labor between the fixed and variable categories. However, the savings generated by buying an additional 100,000 units above an initial million, for example, will generally be so small that the cost of parts and labor will be referred to as a variable cost and thus can be thought of as being added directly to *bt1*.

Once base case costs have been assigned, price is easily computed from Eq. C.4, by using the price elasticity calculated as described above. With the new price in hand, sales (*Q*) can be computed from price and operating-cost elasticities. Revenue is now just $R = P * Q$, and economic income is just $R - C$. Assets are those of the calibration case plus the new capital resulting from 1990 NAECA standards, and equity is computed from the debt-to-equity ratio. This calculation of equity is the last essential calculation for the base case.

The long-run analysis: changed standards

The analysis of the long-run effect of a change in standards from their 1990 NAECA level is essentially the same as the analysis of the base case. New costs are divided between fixed and variable categories in the same way and added to the base case costs. From there, the calculation proceeds in exactly the same way as above.

C.2.2 Structural Assumptions

The cost structure. Costs are assumed to have two components: one fixed and one proportional to quantity.

$$EC = FC + MC_q \cdot Q$$

The asset structure. Assets are assumed to have the same two components.

$$A = A_0 + A_q \cdot Q$$

Demand elasticity. The demand elasticity with respect to life-cycle cost experienced by a single firm is assumed to be independent of price and operating cost over the relevant region. This means that if the industry raises price, the percentage change in demand caused by a 1% change in price remains the same as before the price increase.

Optimizing behavior. A firm is assumed to maximize revenue minus economic cost ($R - EC$).

Debt-to-equity ratio. The debt-to-equity ratio is assumed to remain constant while the firm finances any investment necessary to meet standards. It is generally assumed that firms have some D/E ratio that they consider optimal, and there is no reason for standards to change this figure.

Amortization of capital costs. It is assumed that the one-time capital cost is to be amortized over its life (typically seven years), that its cost is the weighted average after-tax cost of capital, and that depreciation is straight-line over the tax life.

Structure of cost resulting from changes in standards. Engineering costs, if they are separated from capital costs, are assumed to be entirely fixed. The cost of capital is assumed to be partly fixed and partly variable (proportional to shipments). Parts and labor are assumed to be variable costs.

C.2.3 Description of Modules

The LBL-MIM is a Lotus 1-2-3 spreadsheet that is organized into 12 modules or panels. A flowchart depicting the main connections among these appears in Figure C.2, and a brief description of each is given below. Starting with subsection C.2.3.1, each panel is given a full description.

MIM Modules and Primary Routes of Data Flow

Figure C.2 MIM Modules and Primary Routes of Data Flow

1. *Control Panel.* This module displays nine key variables and their control factors, plus a summary of crucial results. The control factors are normally set to one, but can be changed to test the model's reaction to any of the control variables. The change in results is immediately displayed in the lower part of the control panel.
2. *Monte Carlo.* The nine control variables can be selected randomly from probability distributions determined by the variables' standard errors and median (estimated) values. The Monte Carlo module is designed to record many such runs and display the mean value and standard deviation of six outputs: percentage change in price, sales, revenue, and net income, plus the change in ROE in the long and short runs.
3. *Accounting.* The Accounting module gives a summary, in the form of a simplified income statement, of the financial impact of standards on the firm. In addition, a summary of the financial impacts of standards from an economic point of view is shown at the bottom of the page.
4. *Engineering Inputs.* The Engineering Inputs module accepts as input raw engineering data that are used elsewhere in the model for the impacts analysis. These data include incremental variable costs, capital costs, engineering costs, and changes in unit energy consumption for the products being analyzed.
5. *Standards Levels.* The Standards Levels module provides the same data as the Engineering Inputs module, except that the data have been processed by the LBL-REM and/or the "Cost Conversion" module (12) and are presented for the standards levels being analyzed.
6. *Costs, Sales, and Revenues.* This module uses prices, markups, market shares, and industry shipment levels to compute variable cost of goods sold and revenues for a single prototypical firm. Changes in operating cost, capital cost, and engineering expense are also computed here.
7. *Financial.* The Financial module computes the weighted average cost of capital and a factor describing how costs depend on revenues.
8. *One-Time Cost Amortization.* The One-Time module derives amortized costs from the one-time capital cost and one-time engineering expense associated with the imposition of new standards.
9. *Long-Run Model.* This module does most of the economic calculations. Its calibration phase estimates the markup over variable cost, which is used to estimate new prices once standards have been imposed. These prices are then used to compute sales, and, from sales, all other descriptive variables.

10. *Short-Run Model.* This module modifies the price computed by the long-run module in order to take into account the possible short-run effects of excess capacity. An estimate of the responsiveness of price to changes in demand during the business cycle is combined with the change in demand predicted by the long-run model.
11. *Sensitivity and Profit Charts.* This module produces two charts. The first shows how profit is affected by a one-standard-deviation change in each of the control variables. These changes are all made with the standards level set to its middle value. The second chart shows how profits change as the standards level is changed, but all control variables are kept at their base value.
12. *Engineering-to-Standards Conversion.* This module weights the costs given by the engineering model in proportion to the number of products of a particular design that will be produced at any given standards level and thereby generates the costs for that level. These costs appear in the Standards Level module.

C.2.3.1 Control Panel

The control panel displays the nine most important input variables of the model and allows the user to easily adjust them. These variables are described below. The *Input Values* are the best available estimates of the relevant variables.

The control panel has one control for each input variable. The controls, found in the column labeled *Cntrl*, allow the *Input Values* to be modified to become the *Model Values* before they are used by the model. The controls work as follows: when a control is set to zero, its *Input Value* becomes a *Model Value* without any adjustment. When a control is set to 1, its *Input Value* is increased (in absolute value) by approximately one standard deviation to become a *Model Value*. Because the error distributions associated with the *Input Values* are not normal, they are not changed by exactly one standard deviation when the control is set to plus or minus 1. A control value of ± 1 actually changes an *Input Value* by an amount sufficient to make it just as unlikely as a point that is one standard deviation from the mean using a normal distribution. Consider an *Input Value* that is known to be strictly positive and have a mean of 5 and a standard deviation of 3. Setting its control to -2, which would otherwise change its value to -1 (an impossibility) actually only changes it to some small but positive value. This value would be just as unlikely as a point -2 in a normal distribution.

The *Variation* column shows either the standard deviation of an input variable if the variable is normally distributed, or the coefficient of variation (*S.D./mean*) if the input variable is non-normal.

At the bottom of the control panel is a short output summary, which shows the five key output variables: *shipments*, *price*, *revenue*, *net income*, and *ROE*. The first column gives the output values in the base case—that is, the case in which the 1996 (or which ever future year is relevant for the product under consideration) standards are the same as the 1990 standards. The

second column assumes some particular change in standards and gives long-run values—that is, values that would hold after capacity adjustments (by about 1999). The third column gives the percentage change from the base case to the new standards case for each of the five key output variables. The fourth column, labeled *Previous Change*, simply lists the results of the previous run to use as a comparison with the results of the current run. The fifth column lists the results from the short-run part of the model (i.e., the estimated output values for the period immediately after the imposition of the new standards).

The following is a list of the nine key input variables that appear as control factors in the Control Panel module:

1. The industry's price elasticity of demand (IPE),
2. The consumer discount rate (RD),
3. The market cost of capital financed through equity (ECC),
4. Economic profit: the industry's ROE minus normal ROE (EP),
5. The long-run fixed part of costs and assets (FCA),
6. The long-run fixed part of one-time costs and assets (F1X),
7. One-time capital costs resulting from the change in standards (CC.L),
8. Variable cost of goods sold after the change in standards (dVC.L), and
9. The short-run price response to demand (SRPR).

C.2.3.2 The Monte Carlo Module

This module estimates the standard errors of the six most important output variables by randomly choosing the nine control variables in accordance with estimates of their standard errors, running the model, and recording the six output variables. This procedure is repeated up to 400 times. Afterwards, the mean and standard deviations of the 400 computed values of each output variable are computed and displayed near the top of the Monte Carlo module. The top row, labeled *Value*, is the most recently computed random set of outputs.

The first four output variables are the percent change resulting from standards, in output (Q), price (P), revenue (R), and net income (NI). The last two variables are changes in long- and short-run return on equity (ROE). Because these last two variables are percentages, the changes presented here are simple differences between their values before and after a change in standards.

C.2.3.3 The Accounting Module

The Accounting Summary consists of a simplified income statement that is presented in standard form, along with several key financial ratios and figures that highlight the firm's financial position. The income statement and financial ratios are presented for the 1989 calibration case, a 1996 base case that includes the impact of the 1990 NAECA standards, and a 1996 new standards case that lists the firm's financial results under the new standards being analyzed. Thus, the financial impacts of the new standards are easily seen by comparing the two 1996 scenarios. To highlight the results, a final column in the accounting summary indicates the percentage change from the 1996 base case to the 1996 new standards case.

Table C.1 Accounting Module

Item	Formula
Earnings Before Interest and Taxes	EBIT = Revenue – Total Expenses
Total Expenses	Does not include interest or taxes
Interest	(Interest rate <i>mb</i> Debt ratio <i>mb</i> Assets) – Interest earned on "Cash" assets
Taxes	(EBIT – Interest) <i>mb</i> Tax rate
Net Income	EBIT – Interest – Taxes
Gross Margin	1 – (Variable Cost of Goods Sold/Revenue)
Return on Sales	Net Income/Revenue
Return on Assets (ROA)	(EBIT – Taxes – (Tax rate <i>mb</i> Interest))/Assets This calculation eliminates interest tax shield
Return on Equity (ROE)	Net Income/Equity

A second table at the bottom of the Accounting Summary page lists financial data for the firm using figures that are necessary for an economic analysis. Note that the assets and expenses are broken down into two categories: fixed and proportional to quantity produced. These proportionalities have economic significance when the price markup is computed, and for that reason they are reported separately in the economic analysis.

Note that "one-time" (*I-X*) in the Accounting module refers to expenses incurred because of the change in standards.

C.2.3.4 The Engineering Inputs Module

The Engineering Inputs module receives all the engineering costing data and energy consumption data for the product classes being analyzed. The data include the incremental variable cost and change in unit energy consumption for each design option. They also include the one-time engineering expense and capital costs incurred in meeting the new standards; the module assigns these costs to design options and product classes where appropriate or necessary. The various components of the module are described below:

1. *Increment in additional UVC (Unit Variable Cost):* Engineering input data. Each "increment" is measured relative to the previous engineering design. The numbers refer to 1989 dollars per unit produced and are displayed only to the nearest whole dollar.
2. *Additional UVC above Level 0 cost (VCS.E):* "Additional" UVC is measured relative to the 1989 calibration case, which is shown as level 0. In other words, this table is a cumulative version of the above "incremental" table.

3. *Annual unit energy consumption per year:* For electric appliances, these engineering input data are the energy use per year measured in kilowatt hours. For natural gas appliances, the energy use is measured in Btus (generally millions of Btus but sometimes in thousands. Specifics are in the relevant Appendix C for the product concerned.)
4. *Capital costs:* These engineering input data are given on a per-unit basis amortized (with zero interest) over seven years.
5. *Additional capital cost (above Level 0 Cost):* This row translates the amortized capital costs into total one-time capital costs. The numbers refer to 1990 dollars per unit produced.
6. *Total capital and engineering costs (CCEE.E):* The top row of this matrix is the sum of the columns in the "additional capital cost" matrix. Thus the CCEE.E matrix gives the combined added capital cost for all classes of an appliance. The maximum number (from the highest level) in this row is called *MxCC* and is used to assign engineering expenses to the levels as follows:

$$EE_i = EE:CC \cdot MxCC \cdot CC_i$$

where *EE:CC* is the ratio of total engineering expense to total capital cost, and *EE_i* and *CC_i* are expenses for level "i." The CCEE.E matrix contains the capital and engineering costs that are used as inputs to the rest of the model. The Long-Run module calculates the average prices for all classes and for each level.

C.2.3.5 The Standards Levels Module

The Standards Levels module provides the same information as the Engineering Inputs module except that instead of listing the cost and energy data for various engineering design options, it lists the data for the various standards levels being analyzed. The detail for each product is supplied in the relevant Appendix C for that product's volume.

The data that appear in the three REM panel tables for each product—VCS.R, KWS.R and CCEE.R—may correspond exactly to some specific engineering levels or, if it has been determined that the manufacturer, when faced with certain standard levels, would use a mixture of engineering designs, then the "Engineering-to-Standards Module" appropriately averages the engineering data and places the results in the three REM tables. The exact mixtures of engineering options are determined by the LBL-REM.

The top section of this module allows the user to determine what standards will be analyzed in a particular run. The module is used interactively by the user, who can choose "levels" LEV.B and LEV.N, which correspond to the Base case and Long-Run case, respectively.

The bottom numbers in the "LevIn" matrix determine whether these levels will refer to "standards levels" or "engineering designs." The top numbers specify the exact level or design.

The values in the "LevIn" matrix determine what values are placed in the bottom two matrices when the model is run. For example if in "LevIn," $LEV.B = 4$ and $SIE.B = 0$, then the columns of VCB, KWB, CCB, and EEB will contain data for the fourth engineering design option. Changing $SIE.B$ from 0 to 1 would cause all of these data to be replaced with data for the fourth standards level.

C.2.3.6 The Costs, Sales, and Revenue Module

This module has two functions. First, it provides the Long-Run Model module with several inputs; these are averages. Second, it uses many of the data from the input pages and processes these data into prices, quantities sold, and revenue. These intermediate output data are then used in the financial and economic summaries to give output results, which are used for the analysis of the impact of standards. Table C.2 lists the equations that are used in the Costs, Sales, and Revenue module.

In the new standards case, the variables are named with a ".N" suffix instead of a ".B" suffix. The "Totals" row gives the weighted average change in UVC ($dVC.B$), the weighted average change in price, the new weighted average price ($P.B$), the firm's total revenues ($\sum (Ri), R.B$), the weighted average change in operating costs ($OC\%.B$), and the total firm shipments ($Q.B$). $P.B$, $Q.B$ and $R.B$ are actually computed in the Long-Run module.

The first stage in this module is setting up the 1990 calibration case, which uses known information about industry shipments, product class market shares, prototypical firm market shares, markups for each of the product classes, and baseline unit variable costs to calculate the prototypical firm's shipments for each product class, its cost of goods sold, and its revenue. Also calculated are a weighted-average unit variable cost, selling price, and markup. Markup is calculated from data on the ratio between the highest and lowest markups (*ratio*) and the typical markup (*mid*).

Table C.2 Equations Used in the Costs, Sales, and Revenue Module

Item	Calibration Case Formula or Definition
Size	Prototypical firm market share
Industry Shipments	Annual industry shipments for a product class
Relative Shipments (Q%)	Product class market share (product class units sold/total units sold)
Shipments (Q.1)	Product class shipments for a prototypical firm
Price (P.1)	Retail price/retail market
Revenue (R.1)	Price <i>mb</i> Shipments
Markup (M.1)	$1 + (P.1 - BB)/AA$
Unit Variable Cost (UVC.1)	$P.1/M.1$
Weighted UVC	UVC <i>mb</i> Relative Shipments (Q%)
Weighted Change in UVC	Change in UVC <i>mb</i> Relative shipments (Q%)
Weighted Change in Price	Change in Price <i>mb</i> Relative shipments (Q%)
Weighted Change in Price	$Wghtd\ dp = q\% * M.1\ mb\ Change\ in\ UVC$
Mark.B	$(P.B - P) / \sum Wghtd\ dP$
New Price (Pi.B)	$P.1 + Mark.B * M.1\ mb\ Change\ in\ UVC$
Operating Cost Ratio	1996 UEC/1990 UEC
New Shipments (Qi.B)	Operating Cost Ratio <i>mb</i> Relative Shipments (Q%)
New Revenue (Ri.B)	$Q\% * Q.B$
Weighted Operating Cost Ratio	$Pi.B * Qi.B$

The next stage in the Cost, Sales, and Revenue Module calculates the changes necessary to produce the 1996 base case (1990 NAECA standards) and the 1996 new standards case. The calibration case is used as a base, and the changes in unit variable cost and unit energy consumption are fed in from the REM panel. From this input, new unit variable costs and prices are calculated for each of the product classes. The model then uses known price and operating cost elasticities to calculate changes in shipments for each of the 1996 cases. For each of the 1996 cases, the model calculates the firm's new shipments, revenue, and the weighted- average change in unit variable cost and price.

The manufacturer markup listed in the panel is used to calculate the baseline model prices, but it is *not* used in calculating the manufacturer prices for the 1996 base case or the standards levels. In these cases, LBL-MIM uses an economic markup to determine prices.¹⁶ This markup is on *economic* variable costs, which are a broader category than the typical business definition of variable costs. The markup varies depending on elasticities and changes in prices and operating costs at different standards levels. Thus, prices at different standards levels do not exactly reflect the manufacturer cost times the manufacturer markup.

C.2.3.7 The Financial Module

The Financial module lists the financial characteristics of the prototypical firm being analyzed. Some of the inputs are used to calculate intermediate outputs of financial characteristics of the firm. The financial inputs and intermediate outputs are then used elsewhere in the model when the impacts of standards are calculated.

A number of variables in the Financial module are non-standard and thus require explanation. First, in order to make the model adjustable to a particular point in time when the size of the firm may be different from what it was in the year in which the data were collected, some of the inputs are listed as ratios proportional to revenue. For instance, the historical ratio between depreciable assets and revenues for the room air conditioner manufacturing industry (called *DA:R*) is 0.224. This is used by the model to compute a value for depreciable assets at some typical year in the future after standards have changed by multiplying *DA:R* by revenue in that year.

Table C.3 Financial Module

Item	Formula
Depreciation (<i>DR:R</i> = Depreciable assets as a percentage of revenues)	Average depreciation rate $\times$ <i>DR:R</i>
Pre-Tax Equity Cost of Capital (PECC)	Equity Cost of Capital/(1 - Tax Rate)
Weighted Average Cost of Capital (WACC)	(Debt ratio <i>mb</i> Interest rate) + (Equity ratio <i>mb</i> PECC)
After-Tax WACC	WACC <i>mb</i> (1 - Tax rate)
Return on Equity (ROE) (ECC = Equity Cost of Capital) (This ROE figure is the expected ROE for a prototypical firm.)	After-Tax ECC + Economic Profit

A complication may occur if a value changes in proportion to revenue between now and the typical year, but under standards it is expected that a portion of the value will remain proportional to revenue while a portion of the value will not change with revenues because of

¹⁶For a thorough description of how markups are derived and used in LBL-MIM, see Appendix C.2.1.

the change in standards (i.e., it is "fixed"). In this case, that value is analyzed as having a "variable" and a "fixed" component, where "variable" and "fixed" are used with respect to a change in standards.

C.2.3.8 The One-Time Cost Amortization Module

Crucial to this analysis are the capital cost and engineering expense that the industry will incur because of the change in standards. This module takes as input from the Engineering Inputs Module the estimate of the total value of these two one-time expenses and reduces these one-time expenses to annual expenses. To annualize (or "amortize") these costs, the module takes into account: the expected life of the new capital, the tax life of the investment, the weighted average cost of capital, and the timing of the investment relative to any capital that is being replaced.

The amortized engineering expense and capital cost are calculated for the change from the 1990 calibration case to the 1996 base case that includes the 1990 standards, and for the change from the 1990 calibration case to whatever standards case is under consideration. Also, the average value (over the amortization period) of the new capital is computed.

The calculations are based on the following model of investment: new capital will be paid for according to the *CC SCHEDULE*, and engineering costs will be expended according to the *EE SCHEDULE*. These schedules give expenditures for the four years previous to 1993; these expenditures are assumed to occur at the middle of each year. They are assumed to be financed by debt and equity in the firm's normal debt-to-equity ratio. Tax benefits will accrue over the tax life of the capital. Some part (0%–10%) of the capital expenditure is assumed to be for new plant and equipment that do not take the place of anything in existence; the remainder is assumed to replace inadequate existing equipment. The replaced equipment is assumed to have had the same potential lifetime (*L*) as the replacing equipment and is assigned a certain age. If the new equipment replaces old equipment that would soon have needed replacing anyway, savings are included at the time the natural replacement would have occurred.

The computed annualized cost tells what constant real dollar payment would need to be made each year in order that at the end of the capital's useful life all of the issued debt could have been paid off, and all of the issued equity could have been repurchased.¹⁷ Since standards are assumed to last indefinitely, new capital will need to be purchased at the end of this cycle; but of course the next cycle starts with a clean slate and repeats the same process we have just described. This process can repeat indefinitely with no change in amortized payments.

This procedure overestimates the burden to the firm in two ways. First, engineering costs should actually be lower, possibly zero, in the second cycle. Second, because industry is constantly improving the efficiency of product lines, lines would undoubtedly be much nearer to

¹⁷ Of course tax benefits are counted toward eliminating debt and equity.

meeting the standards by the beginning of the second cycle. Thus, much of the capital equipment re-installed at the end of the first capital's lifetime would have been a normal expense by this date (around 2001).

For the interested reader, the details of the calculation method are given in Table C.4.

Table C.4 One-Time Cost Amortization Module

Item	Definition	Formula
DR [ER]		Debt [Equity] / (Debt + Equity)
T	Tax rate (34%)	
ECC	Equity cost of capital	
PECC	Pre-tax ECC	$ECC/(1 - T)$
WACC	Weighted average CC	$DR * I + ER * PECC$
ATWACC	After-tax WACC	$WACC * (1 - T)$
ATR	Continuous ATWACC	$\ln(1 + ATWACC)$
CCi	Capital cost i years before standards	
EEi	Engineering expense i years before standards	
WCCi	(see 1-X Cost module)	$CCi * \exp(ATR * i)$
WEEi	(see 1-X Cost module)	$EEi * \exp(ATR * i)$
LTC	(see 1-X Cost module)	Sum of WCCi over 4 years
LTE	(see 1-X Cost module)	Sum of WEEi over 4 years
EMRT		$\exp(-ATR * TL)$
EMRL		$\exp(-ATR * L)$
BN	"Tax benefit rate"	T/TL
RTL	Remaining tax life	$\max(TL - AGE, 0)$
PVD	Present value of depreciation	$-BN * (1 - EMRT)/ATR$
OCS	Old capital savings	$-(1 - \%NC) * \exp(-ATR * (L - AGE))$
OCTL	Old capital tax loss	$(1 - \%NC) * BN * (1 - EMRT)/ATR$
TBS	Tax benefit from scrapping	$-RTL * BN * (1 - \%NC)$
PVCC	Present value of CC	$1 + PVD + OCS + OCTL + TBS$
APVCC	Adjusted for lead timer	$PVCC * LTC$
CCLF	CC amortization factor	$ATR * APVCC/(1 - EMRL)$
EELF	EE amortization factor	$LTE * (1 - T) * ATR/(1 - EMRL)$
AFB	(see One-Time Cost module)	$\frac{1 - ATR * L * EMRL/(1 - EMRL)}{1 - EMRL}$
AFC	(see One-Time Cost module)	$\frac{1 - ATI * TL * EMRT/(1 - EMRT)}{1 - EMRL}$
B:T	(see One-Time Cost module)	$(1 - EMRT)/(ATR/BN + 1 - EMRT)$
AFF	Average asset factor	$B:T * AFB + (1 - B:T) * AFC$

Table C.4 should be read in conjunction with the One-Time Cost Amortization module. Note that the calculations are all done with continuous interest and discount rates, which makes it necessary to convert *ATWACC* to a continuous equivalent cost of capital (*ATR*) by taking the natural log of $(1 + \text{ATWACC})$. The continuous rate is equivalent to, and for small rates it is numerically close to, the annual rate. The continuous time formula for the present value of \$Y received t years in the future is $Y \cdot \exp(-rt)$, where r is the discount rate and $\exp$ denotes exponentiation. For a constant stream of income at \$Y per year for L years, the present value is $Y \cdot (1 - \exp(-rL))/r$.

The most important output of this module is the amortized cost factor *CCLF*, which is constructed by summing the following five present values: (1) The initial cost, which is normalized to 1 in order to produce a cost factor instead of an actual cost. (2) The present value of the tax benefit from straight-line depreciation of the initial cost. (3) Present value of savings from not replacing old capital at the end of its normal life if it has already been replaced with new capital to meet standards. (4) The tax benefit from the one-time depreciation of the old capital when it is scrapped. (5) The loss of tax benefit from the old capital after it has been scrapped. The sum is then adjusted for the fact that investment must start before the implementation of standards. All that is left to do now is to convert from a present value to an equivalent constant stream of payments that continues for the lifetime of the capital. The formula for this equation is shown in Table C.4.

Because capital depreciates, its average value is lower than its initial value. In order to derive the factor *AAF*, by which the initial value should be multiplied to arrive at the average value, it is necessary to account for the exact path by which the capital depreciates. Since the value of a piece of capital is, at any time, simply the present value of its future income stream, the value of the depreciated capital as a function of time can be found from the stream of income that the capital will generate. If that stream has a constant flow for a period of T years, then the depreciated value of a unit of capital is

$$DF(t) = \frac{1 - e^{-r(T-t)}}{1 - e^{-rT}}$$

Now if that capital is held for a period of L years, it makes sense to ask what the average value of the asset is over the L years. Because of discounting, a unit of capital now should weigh more heavily than a unit of capital later. This is properly taken into account by requiring the following equivalence:

$$PV(DF(t)) = PV(AAV)$$

where $PV()$ is the L -year present value operator, and AAV is the average asset value corresponding to $DF(t)$. This equation can be solved for AAV , to find the following:

$$AAV = \frac{1}{1 - e^{-rL}} \left[1 - \frac{rT e^{-rT}}{1 - e^{-rT}} \right]$$

This would be the end of the problem— AAV would be the sought-for average asset factor—except for the fact that the asset of interest does not generate a constant stream of income for T years before falling to zero for the remaining $L - T$ years. Instead the income stream of interest is made up of T years of constant tax benefit and L years of (roughly) constant production by the capital. Each of these streams separately fits the description of the problem that has been solved. The solution to this new problem is just the average of the solutions for the two separate problems. For example, if 20% of the total stream is tax benefit that comes to an end after T years, while the remaining 80% continues for the full L years, then the AAF of this combined stream should be 20% of the way from the tax-benefit asset factor to the production asset factor.

The variable $B:T$ gives the fraction of the total stream made up of tax benefits. The factors AFB and AFI are the average asset factors for tax benefits and the productive income of capital respectively, and AAF is the weighted average of these two using $B:T$ as the weight for AFB .

At the bottom of the One-Time Cost Amortization module are found the capital and engineering cost for the base and long-run levels, and the coefficients of variation associated with each. The three factors just derived, $CCLF$, $EELF$, and AAF , can be applied to CC , EE , and again CC , respectively (for either the basecase or long-run case), to derive the three "amortized" outputs.

C.2.3.9 The Long-Run Model Module

The Long-Run Model module is the heart of the LBL-MIM. It does all of the computations concerning a typical firm's behavior. It proceeds in three stages. The calibration stage uses data on present costs and profit to estimate the firm's markup. The second stage estimates the industry's situation in 1990, after it has met current NAECA standards. The third estimates a typical firm's situation with more stringent standards than the current NAECA standards. A detailed discussion of the economic assumptions and results used by this section can be found in C.2.1.

Notation. The following naming conventions have been followed with the variables in the long-run module and generally throughout the LBL-MIM. The suffixes .F and .Q, are used with variables that measure an asset or a cost that is fixed or proportional to sales, respectively. The suffixes .B and .N refer to the 1990 NAECA standards and the 1996 NAECA standards, respectively. A combined suffix such as .BF has the natural interpretation (i.e., a fixed variable in the 1990 NAECA case). The most important variable names in the long-run module are *A* for assets, *TC* for total cost excluding taxes and the cost of equity, *EC* for economic cost (including taxes and equity), *EI* for economic income, and μ for markup above marginal cost, $\mu - 1$.

Calibration. The calibration stage estimates a typical firm's markup over unit variable costs using the following basic economic equation:

$$\text{Markup} = \frac{(\text{Fixed Cost} + \text{Economic Profit})}{\text{Variable Cost}}$$

(In this equation, fixed and variable cost are components of total cost and are not per-unit costs.) *Economic Profit* is the difference between ROE and the equity cost of capital, both of which are obtained by observation. *Fixed* and *Variable Costs* must be deduced from accounting data and from information on economies of scale in the industry.

Assets and costs in the calibration stage are both represented as proportions of revenue, so firm size is irrelevant. This means, for instance, that fixed and marginal costs are not given as dollars and dollars per unit, but instead, total fixed and total marginal costs are described as a fraction of revenue.

Depreciable assets are divided between fixed and marginal according to the input parameter *FCA*, the "fixed part of costs and assets." Inventories are classified as marginal assets, while cash and receivables are classified as proportional to revenue.

Now consider total costs, i.e., those that are tax-deductible. *FCA* is also used to determine the proportion of fixed (total) costs in revenues. Interest loss resulting from cash holdings and a part of general and administrative expenses given by *RGA* account for revenue-related costs. All other costs are marginal, and their amount is deduced from the firm's rate of economic profit.

Because the costs so far are tax-deductible, but revenue is taxable, economic fixed costs are given by the following formula:

$$EC.F = (1 - T) \cdot TC.F + A.F \cdot ER \cdot ECC$$

where *T* is the tax rate, *ER* is the ratio of equity to assets, and *ECC* is the cost of assets. In principle, we could now estimate marginal economic cost (*EC.Q*) directly and use this value to

finish our analysis. However, because costs cannot be measured accurately enough, there could be considerable error in the implied value of economic profit and thus in markup. (Typically a 5% error in total estimated cost will cause a 10% error in implied economic profit.) It is much better to deduce marginal economic cost from economic profit, because economic profit is relatively well-known. This approach gives us the equation for economic marginal cost:

$$EC.Q = 1 - EC.F - EC.R - EP \cdot ER \cdot A:R$$

where EP is the rate of economic profit, and $A:R$ is the ratio of total assets to revenue.

Now the markup is easily computed using the formula given at the beginning of this section on calibration and the model is ready to analyze the 1996 NAECA level of standards.

The base case (1990 NAECA). The base case is labeled in the model as applying to 1996 in order to remind the reader that this is a long-run calculation and not an analysis of what may happen in the year 1990. The variables in both the base case and the new standards case give fixed costs and assets in dollars and variable costs in dollars per unit. Other than this, no adjustments are made to the three components of assets. However, the total asset ratio $A:B$ contains the new assets resulting from NAECA, $LA:B$. This apparent discrepancy is necessary because the costs associated with the new assets are computed separately in the One-Time Cost Amortization module and added to the economic cost.

Total costs are the same as during calibration, except that new variable costs are added into $TC.Q$. Economic costs are computed from A and TC as before, except for the addition of amortized capital costs (LCC), which are divided between fixed and variable according to the input parameter FIX , and amortized engineering expenses (LEE), which are counted as entirely fixed.

The new standards case (1996 NAECA). The case of changes in standards is handled exactly as the base case, except that new values of DVC (the change in variable cost), LA , LCC , and LEE are used.

The remaining descriptive variables. For the calibration case, most of the remaining descriptive variables, Q , P , R , UVC , TC , A , and ROE are known because they are inputs or have been computed. The others are obtained as follows:

$$\text{Variable Cost of Goods Sold} = VCGS = UVC \cdot Q$$

$$\text{Interest, Not } 1X = IC = I \cdot DR \cdot A - C:R \cdot R \cdot (I - ICash)$$

$$\text{Pre-interest Cost} = PIC = TC - IC$$

$$\text{Pre-tax Cost} = \text{PTC} = \text{TC}$$

$$\text{Taxes} = \text{TAX} = (\text{R} - \text{TC}) \cdot \text{T}$$

$$\text{Equity} = \text{EQ} = \text{ER} \cdot \text{A}$$

$$\text{Economic Income} = \text{EI} = \text{NI} - \text{EQ} \cdot \text{ECC} \text{ and}$$

$$\text{Net Income} = \text{NI} = \text{R} - \text{TC} - \text{TAX}$$

$$\text{Return on Equity} = \text{ROE} = \text{ECC} + \frac{\text{EI}}{\text{EQ}}$$

For the base case the above formulas hold with the exception of the one for *NI*, but several other descriptive variables must be computed. Their formulas follow:

$$\text{Q.B} = \text{Q} \cdot \text{LCC}^{(\text{PE} + \text{ICE})}$$

$$\text{P.B} = (\mu + 1) \cdot \text{EC.BQ}$$

$$\text{R.B} = \text{Q.B} \cdot \text{P.B}$$

$$\text{UVC.B} = \text{UVC} + \text{DVC.B}$$

$$\text{VCGS.B} = \text{UVC.B} \cdot \text{Q.B}$$

$$\text{1X depreciation} = \text{X1D.B} = \text{CC.B/L}$$

$$\text{1X interest} = \text{X1I.B} = \text{LA.B} \cdot \text{DR} \cdot \text{I} \cdot \text{LTC}$$

$$\text{1X equity cost} = \text{X1I.B} = \text{LA.B} \cdot \text{ER} \cdot \text{ECC}$$

$$\text{1X tax benefit} = \text{X1T.B} = \text{LCC.B} + \text{LEE.B} - \text{X1D.B} - \text{X1I.B} - \text{X1E.B}$$

$$\text{IC.B} = \text{I} \cdot \text{DR} \cdot (\text{A.B} - \text{LA.B}) - \text{C:R} \cdot \text{R.B} \cdot (1 - \text{ICASH})$$

$$\text{PIC.B} = \text{TC.B} + \text{X1D.B} - \text{IC.B}$$

$$\text{PTC} = \text{TC.B} + \text{X1D.B} + \text{X1I.B}$$

$$NI=R-TC-TAX-LCC.B-LEE.B$$

$$ROE.B=NI.B/EQ.B$$

In the formula for $Q.B$ above, LCC stands for life-cycle cost. This formula is equivalent to the more general one used in the model when the shape parameter (ro) for the demand function is set to one. Setting ro to one simply implements the assumption of constant demand elasticity with respect to life-cycle cost. All of the descriptive variables for the changed standards (long-run) case are computed in exactly the same way as the corresponding variables in the base case.

C.2.3.10 The Short-Run Model Module

During a recession an appliance manufacturing industry will typically face a substantial decline in demand for its product, which will usually cause increased price competition within the industry, with a consequent fall in price. By regressing price on quantity sold and on a time trend, it is possible to estimate the industry's "short-run price response to demand" ($SRPR$). The LBL-MIM requires this as an input to the short-run module. From $SRPR$, the calculation proceeds as follows. Assume for explanatory purposes that demand has fallen because of the change in standards. From $SRPR$ compute the implied fall in price resulting from this unexpected drop in demand. At this new price level, compute a new level of demand that will necessarily be a little higher at the new lower price than at the previous higher price. Now take the new estimate of the level of (and change in) demand resulting from standards and repeat the calculations. After five or fewer repetitions of these calculations, our estimates will converge to a stable answer. At this point, the price correction exactly agrees with the estimated fall in demand, and the estimated demand agrees with the price. At no other values of price and quantity is this true.

Once price and quantity are known, all other variables are easily computed using procedures that have already been described.

C.2.4 Model Inputs

C.2.4.1 Input Generating Assumptions

Many of the necessary input data are not publicly available and so have been estimated from available data or estimated from averages of subjective estimates made by industry representatives. This section describes the various origins of LBL-MIM's data.

Cost data. All cost data are provided by the Engineering Analysis.

Elasticities and operating costs. Industry price elasticity and operating cost elasticity are both supplied by the LBL-REM, as is the change in operating cost that occurs as a result of the change in standards.

Financial data. Financial data are collected from publicly available sources such as Value Line, Standard and Poor's, Moody's, and company reports. The data are often for firms whose operations in the industry under consideration are only part of the firm's total business operations. It is assumed that the relevant division is similar to the firm as a whole.

Amortization data. In order to amortize the one-time costs associated with new standards, the life of new capital is assumed to be seven years, which has been designated by several manufacturers as the period used in their own amortization calculations. Other values relating to such issues as taxation are displayed in the spreadsheet and are generally derived from discussions with industry representatives. The timing of engineering and capital costs come from the Engineering Analysis.

Fixed and marginal costs and assets. Some costs increase in proportion to shipments, and some are fixed. Industry representatives indicate that the bulk of costs and assets are proportional to shipments. The specific values are shown in the Control Panel.

The following sections list and describe the inputs used by the model.

C.2.4.2 Control Factors in the Control Panel

Industry price elasticity. Industry price elasticity measures the way a change in the average industry price for a product will affect the industry's shipments. For example, if the price of a product increases 4% and shipments drop 2% as a result, the price elasticity is -0.5. Because standards will cause the prices of products to increase, this input is obviously crucial in determining the impact of standards on manufacturers.

Industry operating cost elasticity. Industry operating cost elasticity measures the effect of a change in operating costs for a product on the industry's shipments of that product. For example, if operating costs of a product decrease 10% and shipments increase 1% as a result, the operating cost elasticity is -0.1. Because standards mandate more efficient products that will have lower operating costs, this input is important in determining the impact of standards on manufacturers. The operating cost elasticity is calculated from the discount rate supplied by the LBL-REM.

Equity cost of capital. This is the rate of return expected by equity shareholders. This figure is in real terms (i.e., with inflation subtracted). It is an after-tax rate, which means that it is the rate of return the company must earn for its shareholders after its taxes have been accounted for. Data values come from calculations using standard finance equations and public financial data.

Economic profit. Economic profit is the profit earned by a firm above its expected return on equity. In other words, it is the profit earned after all costs are taken into account, including the cost of equity (the market rate of return). A firm makes economic profit only when it has some degree of market power.

Long-run fixed part of costs and assets. This figure is the portion of all costs and assets that is fixed over time, that is, which does not vary with quantity sold or with revenue. It is expressed as a percent of the base case costs and assets. This figure is important, from an economic standpoint, for determining the impact of standards on manufacturers.

Long-run fixed part of one-time capital cost. This figure is the portion of one-time capital costs that is fixed in the long run. Although all capital costs are normally considered fixed in the short run, this portion of the capital costs is spent regardless of the output capacity of the tooling purchased. The other portion of one-time capital costs varies proportionally with the output capacity of the new equipment.

One-time capital costs. Some of the design options used to meet the increased efficiencies mandated by the new standards require additional capital investment in the form of retooling, new equipment, or other capital expenditures. The "one-time capital costs" figure represents the capital costs expended to meet a specific standard being analyzed; this number covers all products in a product type and is an input from the Engineering Inputs module.

Unit variable cost increase. This number is the shipment-weighted average increase in unit variable costs incurred by the manufacturer in meeting the new standards. The incremental variable cost includes raw materials, direct labor, purchased parts, and increased transportation costs. This number is an input from the Costs, Sales, and Revenues module.

Short-run price response to demand (SRPR). When industry demand falls by Y%, price will, in the short run, fall by $SRPR \times Y\%$. This response is expected to die out within a few years, and Y% should be less than 20% when SRPR is used.

C.2.4.3 Engineering Data

Incremental unit variable cost. The incremental unit variable costs are the variable costs associated with design options that increase a product's energy efficiency. This input differs from the variable cost increase input for the Control Panel (Section C.2.3.1) in that it lists incremental variable costs for each design option for each product class of the product type being analyzed, rather than a single shipments-weighted average number. The increased variable cost includes raw materials, direct labor, purchased parts, and increased transportation costs. The data also come in the form of a table that lists the incremental variable cost for each product class for each of the standards levels being analyzed.

Unit energy consumption (UEC) . Unit energy consumption is the annual energy cost (in dollars) of a product. The input data come in the form of a table that lists the UEC for each product class for each design option (and standards level) being analyzed. Electricity is measured in kilowatt hours per year (kWh/y). Gas and oil are generally measured in millions of BTUs (MBTU) though BTUs for some products are measured in thousands (kBTUs).

Engineering expense. This is the total engineering expense associated with producing more energy-efficient products within a product type. The input is given as a table listing the engineering expenses to reach each of the various design options and standards levels being analyzed. The engineering expense also varies depending on the size of the manufacturer. If more than one size of manufacturer is being analyzed for a product type, then the data for all firm sizes are included.

Capital costs. Some of the design options used to meet the increased efficiencies mandated by the new standards require additional capital investment in the form of retooling, new equipment, or other capital expenditures. This input is given as a table listing the cost associated with each design option that requires a capital expenditure. The input is also given in a table listing the total capital expenditure for the design options used to reach each of the various standards levels being analyzed. The capital cost input covers all product classes within a product type, unless noted otherwise. The one-time capital costs resulting from standards vary with the size of the manufacturer. If more than one size of manufacturer is being analyzed for a product type, then input data for all sizes being analyzed are included.

C.2.4.4 Costs, Sales, and Revenues

Industry shipments. Industry shipments are annual shipments for all classes of the product type being analyzed. These inputs are actual data for a 1990 calibration case, an estimate for the 1996 base case using the 1990 standards, and 1996 estimates for each of the new standards levels being analyzed. The 1996 shipments estimates are based on projected product price increases and product price and operating cost elasticities, from forecasts provided by the LBL-REM.

Product class market shares. Each of the classes within a product type has a "market share" of the shipments for that product type. For example, electric storage water heaters account for about 45% of all water heater shipments. The product class market share combined with the total industry shipments give a breakdown of annual shipments by product class.

Manufacturer market share. Each of the prototypical firms in the analysis is assigned a market share appropriate to that segment of the industry. For example, five large water heater manufacturers may each be assigned a 20% market share. The manufacturer market share, combined with the total industry shipments, gives a firm's annual shipments. This figure, combined with the product class market shares, gives a prototypical firm's annual shipments for each product class.

Markups. The markup is the figure used by the manufacturer to determine the firm's selling price for a particular product. It is an increase over the unit variable cost of that product, and it covers overhead, capital costs, and profit. In some industries, manufacturers use different markups on different product classes. The markup input lists the markup used for each class in the product type being analyzed.

Initial prices. This input is the 1990 baseline manufacturer's selling price per unit for each product class. Added to the baseline unit price are the incremental costs of reaching the higher efficiency levels required by standards.

Energy price. This figure is the price ratio of a 1990 kWh to a 1996 kWh taken from the LBL-REM; energy price is used to calculate the change in operating cost from the calibration case to the base case ($OC\%.B$) and to the new standards case ($OC\%.N$).

C.2.4.5 Financial Inputs

Rates of financial costs:

After-tax equity cost of capital. This input is explained in Section C.2.3.1, Control Panel.

Interest rate on debt. This is the interest rate paid by a corporation on its debt. This figure is in real terms (i.e., with inflation subtracted), and is the yield of corporate bonds with a Moody's rating comparable to ratings in the industry being analyzed.

Interest lost on cash. Companies hold a portion of their current assets in the form of cash in bank accounts, marketable securities, and other liquid holdings, all lumped under the term "cash." This category of assets has a cost associated with it because of the cost of the debt and equity associated with all assets. However, companies manage their cash accounts very well and are able to earn interest each day on the cash they are not using that day. The interest earned on the cash accounts tends to be low, since the investment is only overnight and varies from day to day. The interest earned is lower than the cost of the capital used to form the asset. Thus, the cash account costs the company money but the cost is lower than for any of the company's other assets.

Rate of depreciation. This figure is the rate of depreciation on fixed assets for a typical firm in the industry. It is obtained by assuming straight-line depreciation and an average tax life of eight years for the firm's fixed assets. It is then revised by analyzing actual depreciation data from the industry under consideration.

Tax rate. This rate is the average tax rate faced by an industry in 1996. It is based on past data and recent revisions to the tax law.

Assets and costs as a percent of revenue:

Cash. Companies hold a portion of their current assets in the form of cash in bank accounts, marketable securities, and other liquid holdings, all lumped under the term "cash." In the model, this input is expressed as a percent of total revenue.

Inventory and receivables. This figure represents the inventory and receivables assets, expressed as a percent of total revenue. Inventory includes raw materials owned by the company, work in process, and finished goods that have not yet been shipped. Receivables refers to goods that have already been sold and shipped by the firm for which the firm has not yet been paid, but is instead owed money.

Depreciable assets. This figure represents the net depreciable, or fixed, assets of the firm, expressed as a percent of revenue. Depreciable assets are tooling, equipment, production facilities, and other goods that have an original lifetime of longer than one year and thus are depreciated over several years rather than expensed in one year.

General and administrative expenses (G&A). This figure represents the general and administrative and selling expenses for the firm, expressed as a percent of revenue. It is the "overhead" of the company. In the model, this figure does not include engineering, since engineering expense is treated separately because of its relevance for analyzing the financial impact of standards on manufacturers.

Engineering. This figure represents the annual engineering expenses for a firm, apart from the engineering expenses induced by standards, expressed as a percent of revenue. The engineering expense associated with meeting the standards appears on the Costs and Assets of the One-Time Investment page of the model.

Fixed and variable costs:

Fixed part of all costs and depreciable assets. This input is explained in the Control Panel section of C.2.3.1.

Fixed part of one-time capital cost. This input is explained in the Control Panel section of C.2.3.1.

Other financial inputs:

Economic profit. This input is explained in the Control Panel section of C.2.3.1.

Debt-to-equity ratio. All of a firm's assets are paid for either by debt or by equity. The debt-to-equity ratio is used in calculating a firm's weighted average cost of capital. It is also associated with the risk factor of the firm and affects how much money a firm is able to borrow and at what interest rate, so it is important in the analysis of the impacts of standards.

Markup on a typical model. This figure is the markup used by a firm in determining the manufacturer's selling price. It is the markup used on the unit variable cost of a typical product in the industry being analyzed.

Ratio of highest to lowest markup. In some industries, manufacturers use different markups on different product classes. If such a situation exists in the industry being analyzed, this ratio indicates the range of markups used.

Costs and assets of one-time investment:

One-time capital cost's life. This input is the productive life of the equipment purchased to meet the standards, expressed in years. The number is also used as the period of time over which the one-time costs induced by standards are amortized.

One-time capital cost's tax life. This input is the tax life of the equipment purchased to meet the standards, expressed in years.

Percent additional one-time capital. Meeting standards may require both the addition of new capital that replaces nothing, and the replacement of old capital that has become inadequate. This variable tells what percent of new capital is additional rather than for replacement.

Age of old (replaced) capital. This input gives the age, in years, of the old capital that gets replaced because of the new standards. Under standards, some old equipment will get scrapped before the end of its productive life and replaced by new equipment. Depending on the age of the replaced capital, tax and/or economic consequences are factored into the calculations of the cost of the new equipment.

One-time capital cost and engineering expense schedules. The one-time capital cost and engineering expense schedules are inputs that list the costs incurred over time for preparations to meet the new standards. The capital costs and the engineering expenses are listed together in a table. A percentage of the total cost of each of these categories is attributed to each year before the standards go into effect, because that is when these expenses will occur. These cost schedules allow the model to be more accurate in calculating the present value of the amortized costs, rather than assuming that the costs all occur when the standards go into effect.

C.2.5 Model Outputs

C.2.5.1 Control Panel Outputs

The Control Panel outputs are the summary outputs of the model. This output section enables the reader or model user to see at a glance the main short-run and long-run impacts of standards on a few key variables: shipments, price, revenue, net income, and return on equity.

For each of the five variables listed above, the Control Panel output table lists the base case number, the new long-run number, and the percentage change between the two. The table also lists the percentage changes for these variables from the most recent previous run for comparison purposes. The last column in the output table lists the short-run results for each of the variables.

The base case numbers refer to 1999 values if the 1990 standards are in effect but if no new 1996 standards are implemented. The long-run numbers are the model's estimates for these variables when new 1996 standards are implemented and after manufacturers have had time to adjust to the changes and find new optimal selling prices and production quantities. The short-run numbers are the model's estimates of impacts on manufacturers in the short run, before they have time to find a new optimum.

Shipments. Shipments are the total units sold by a prototypical firm in a given year, expressed in millions of units. The shipments variable is the sum of shipments for all product classes within a product type. Shipments data are calculated on the Costs, Sales, and Revenues page.

Price. Price is the shipments-weighted average of the manufacturer's selling prices for the different classes within the product type being analyzed. Price data are calculated on the Costs, Sales, and Revenues page.

Revenue. Revenue is the amount of money received by the manufacturer for the products it has sold. It is the sum of the revenue for each of the product classes being sold by the manufacturer and it is expressed in millions of dollars. It can also be calculated by multiplying the annual shipments times the shipments-weighted average price. Revenue data are calculated on the Costs, Sales, and Revenues page.

Net income. Net income is the after-tax profit made by the company, expressed in millions of dollars. Net income and the associated return-on-equity are primary measures of a company's financial performance. In LBL-MIM, net income is calculated in the Accounting Summary.

Return on equity (ROE). Net income is a dollar amount that varies in part simply because of a firm's size, and ROE adjusts for different-sized companies by giving net income as a proportion of stockholders' equity. It is the return an investor makes on his investment in the stock of a particular company. ROE is calculated in the Accounting Summary.

C.2.5.2 Accounting Summary Outputs

Net income. See the Control Panel section above for a description of net income. In the Accounting Summary, net income is expressed in thousands of dollars rather than millions.

Gross margin. Gross margin shows, on a percentage basis, how much revenue remains after the variable cost of goods sold is accounted for: $GM = (R - VCGS)/R$.

Return on sales. Return on sales is net income as a percentage of revenue.

Total assets. Total assets is the sum of all of the prototypical firm's assets. This includes cash, inventory, and receivables; depreciable assets; and in the case of new standards, the one-time assets acquired to meet the standards.

Return on assets. Return on assets is the total return on the debt and equity portions of a firm's assets. It is a measure of how productively a firm's assets are being used. The interest paid on debt instruments and the net income that belongs to equity shareholders are the returns on the firm's assets. The returns are divided by the total assets of the firm to calculate return on assets.

Equity. Equity is the portion of a firm's assets owned by the stockholders of the firm. It is the difference between a firm's assets and its liabilities. In this model it is calculated by multiplying the equity percentage obtained from the debt-to-equity ratio times the total assets figure.

Return on equity (ROE). See the Control Panel section above for a description of ROE.

C.2.5.3 Economic Analysis Outputs

The economic analysis outputs give a clear and concise picture of what is going on in the company from an economic standpoint. Most of the outputs show up in the other two outputs sections. Shipments, price, and revenue are discussed in the Control Panel section. The total assets number is calculated in the Accounting Summary section, and the economic analysis output breaks down total assets into three categories: cash, inventories, and depreciable assets. Expenses are looked at from an economic point of view rather than an accounting one. Thus expenses are broken down into fixed expenses and expenses that vary with the quantity produced.

C.2.5.4 Monte Carlo Outputs

The Monte Carlo outputs section lists the results of six key measures of impact when the Monte Carlo option is used. For key input variables, the Monte Carlo option randomly generates values around the best available estimates of their true values. As a result, the outputs vary from run to run, and the model can calculate means and standard deviations for the key measures of impact. It is then possible to bound the estimates of impact and attribute a degree of certainty to them.

The Monte Carlo Outputs section is a table that lists for each variable the value of the current iteration, the mean of all the iterations done in the current run, and the standard deviation

of the results. It then lists in chronological order the results of all the iterations done in the current run.

The measures of impacts are percentage change in shipments, percentage change in price, percentage change in revenue, percentage change in net income, and percentage point change in ROE for both the long-run analysis and the short-run analysis. See the Control Panel section (Section C.2.3.1) for a more complete description of each of these outputs.

C.2.5.6 Retail Prices

One important role of LBL-MIM is to provide estimates of retail prices of appliances at different standards levels for the LBL-REM and the Life-Cycle Cost analysis. The primary input for the retail price calculation in LBL-MIM is MIM's estimates of manufacturer prices. The manufacturer prices are derived from base manufacturer costs, engineering production costs, and appropriate manufacturer markups for each product. The base manufacturer cost is derived from current retail price data for appropriate product classes (e.g., electric and gas storage water heaters). These prices are divided by both the retail markup for the product and the wholesale (manufacturer) markup. This calculation is described in more detail in the description of the Costs, Sales, and Revenue module (C.2.3.6).

The model generates a matrix of manufacturers' selling prices for each product class at each standards level. These manufacturers prices are then multiplied by an estimate of the manufacturer-to-retail markup appropriate for the product class, which produces the retail price estimate (this markup varies depending on the product analyzed. See Appendix C of the relevant products volume for specific details). Retail prices are given in 1990 dollars.

C.3 INPUT DATA AND DATA DEVELOPMENT FOR THE EIGHT PRODUCTS

The LBL-MIM input data for the fluorescent lamp ballast, TV, water heater, pool heater, direct heating equipment, mobile home furnaces, room air conditioners, and kitchen ranges and ovens (including microwave ovens) model runs are described in the Appendix C in their respective volumes of the TSD.

APPENDIX D. MAINTENANCE COSTS FOR COMMON APPLIANCE COMPONENTS

D.1 INTRODUCTION

This appendix describes the analyses used to characterize the maintenance costs for several components that are common to more than one appliance. Maintenance costs for components that are unique to a particular appliance are described in the volumes of this document that treat that appliance.

Analysis Approach and Results

Maintenance cost has been characterized for this analysis as a present value cost increment to be added to the purchase price of an appliance. Thus, the maintenance cost can be described as $C_{\text{maint}} = f \cdot C_0$, where C_0 is the cost of the maintenance procedure in the year that it occurs ("n" years after the appliance purchase), and $f = (1 + d)^{-n}$ is the present value factor that discounts the C_0 value to the purchase time using discount factor d, taken here as 6%. Using this approach, the maintenance cost (C_{maint}) for any component can be obtained from two values: a cost C_0 and a lifetime n. The discount factor is a real discount factor since the analysis assumes constant dollars.

COST DATA. National average values of C_0 were calculated by first obtaining regional cost average values, C_0' , for the San Francisco Bay Area. These C_0' values, in 1990 dollars, were obtained from a survey consisting of phone interviews with principal service department personnel at four heating and air conditioning installation companies. After averaging the cost values from the different service organizations, a location multiplier of $(1/1.367 =) .732$ was used to adjust the costs to a national average value from the San Francisco regional value. The 1.367 value was obtained from a listing of location multipliers for mechanical construction work cost estimation data by the R.S. Means Company (23).

LIFETIME DATA. The service organization personnel mentioned above were also asked in the same survey to estimate the lifetimes ("n" in the above equation) of the subject components, and their responses were averaged in order to obtain values of n for analysis. Values obtained in this way were used with care, since it can be argued that service organizations do not have a good perspective on component lifetimes. Where possible, other lifetime data were used, as will be described below.

RESULTS. Table D.1 presents the values of C_0' and n used for each component. Also presented are the calculated C_0 and C_{maint} values. The following subsections describe the data and assumptions used in obtaining the values shown.

Table D.1 Data and Calculations Used to Obtain Maintenance Costs (1990 \$)

Component Name	(C _o ') San Francisco Regional Cost	(C _o) National Average Cost	(n) Maintenance Lifetime	(C _{maint}) Present Value of Maintenance Cost	Data Source
Standing Pilot	\$73.1	\$53.5	10.2	\$30	survey
Intermittent Ignition	\$249.0	\$182.0	na	\$81 or \$55	survey + analysis
Combustion Fan	\$149.2	\$109.2	11.1	\$57	survey
Burner Box Damper	\$87.0	\$63.6	10.0	\$36	estimate
Condensing Design	\$105.0	\$76.8	7.7	\$49	survey
Two-Stage Operation	na	na	na	\$32 or \$22	estimate
Continuous Modulation	na	na	na	\$64 or \$44	estimate

D.2 STANDING PILOT IGNITION SYSTEMS

Standing pilot systems typically require maintenance for replacement of pilot thermocouples. The values of C_o' (service call cost) and n (thermocouple lifetime) shown in Table D.1 were obtained from survey averages. The average thermocouple lifetime value in the Table also includes lifetime estimates obtained from the mobile home furnace manufacturers.

D.3 INTERMITTENT IGNITION DEVICES (IIDs)

IIDs are common to mobile home furnaces, water heaters, direct heating equipment, ovens, clothes dryers, and cooktops. The IID devices for ovens are considerably different (with more simple controls) than those for the space-and water-heating appliances, so the maintenance costs for ovens are not treated in this appendix. The cost analysis here was generated specifically for direct spark and spark-to-pilot IIDs, and does not necessarily apply to hot surface ignition (HSI) devices. However, the main difference between HSI and spark devices is the actual ignitor element itself, since control modules, gas valves, and ignition sensors happen to be similar in function and maintenance costs no matter what the system. Therefore, the assumption is made here that HSI and spark ignitors have the same maintenance costs. While HSI ignitor breakage rates are probably substantially higher than spark ignitor failure rates at the present, the assumption was made for this analysis that HSI ignitor breakage rates will have been significantly reduced by the time the subject standards take effect (24).

Regardless of the system type, IID systems were considered for this analysis to consist of three main subcomponents: ignitor device, control module, and ignition sensor. After discussions with furnace maintenance organizations, ignitor devices were considered to have negligible maintenance requirements (apart from current HSI breakage replacements). Sensors and control modules were considered separately in terms of cost (C_o) values.

The C_0 values for sensors and control modules were obtained directly from the furnace maintenance organization survey:

Sensor replacement service call:	\$79
Control module replacement service call:	\$170
Total Cost:	\$249

These values represent the total amounts that an appliance owner in the San Francisco area would have to pay for replacement of a defective part. The sensor and control module costs have been added above due to the unavailability of separate lifetime information for sensors. Both sensor and control module were assigned the same lifetime as the control module.

MAINTENANCE LIFETIME (n). The value of n was estimated from information obtained from IID manufacturers and not from the survey results. There were several reasons for using alternative lifetime information in this case. The first reason has been mentioned above. Secondly, it appeared that IID systems in particular are still developing rapidly, and that the estimates for lifetimes obtained from services organizations would be faulty if based on experience from the past.

The lifetime of an IID component must be characterized by the average present value for all possible failure times. In order to achieve such an average, a probability density function (PDF) of failures over time was generated based on information obtained from telephone interviews with manufacturers of IID control modules. A separate lifetime was not available for sensors, so the lifetime for control modules was chosen for sensors as well. Conversations with service organizations indicate that sensor lifetimes are probably shorter than control module lifetimes.

The following data were derived from conversations with IID control module manufacturers:

- Item 1: Control module average lifetime is on the order of 14 years.
- Item 2: The average control module failure rate during the first year of operation is below 2.5%. The value 2.5 was used for this analysis. Failures in the first year are covered under warranty and do not represent a cost to the consumer.
- Item 3: After 10 years of production, yearly IID sales for the aftermarket (repairs) were on the order of 5% of total yearly sales.

Table D.2 presents a tabular summary of the probability density function (Columns A and B) developed using some of the above information. The values are calculated on the basis of unitary maintenance cost (\$1), assuming appliance installation in year 0, and maintenance occurring due to IID failure at some time during the 18 years of IID life. Results (in Column E) are calculated for appliances with a 15-year life (specifically, direct heating equipment) and for appliances with lifetimes greater than or equal to 18 years (specifically, mobile home

furnaces). The assumption is made that the cost of all failures (as accumulated in Column E) does not include the cost of failures occurring in the first year. Using the total cost, $C_0 = \$182$ (given above), the present values for IID maintenance were calculated as follows:

Appliances with 15 years avg. life: $\$182 \times (\$.30/\$1.0) \approx \55
 Appliances with 18 or more years of life: $\$182 \times (\$.44/\$1.0) \approx \81

Table D.2 Calculations for Mean Lifetime of IID units

Year After Purchase	Yearly Fraction of Units Failing (F)	Present Value Discount Factor (f)	Average Present Value of Maintenance ($\$1 \times F \times f$)	Summation of Present Value of Maintenance
Column A	Column B	Column C	Column D	Column E
1	0.025	na	na	
2	0.01	0.890	\$0.009	
3	0.01	0.840	\$0.008	
4	0.01	0.792	\$0.008	
5	0.01	0.747	\$0.007	
6	0.01	0.705	\$0.007	
7	0.01	0.665	\$0.007	
8	0.0175	0.627	\$0.011	
9	0.0275	0.592	\$0.016	
10	0.045	0.558	\$0.025	
11	0.0575	0.527	\$0.030	
12	0.075	0.497	\$0.037	
13	0.0875	0.469	\$0.041	
14	0.105	0.442	\$0.046	
15	0.115	0.417	\$0.048	\$0.30
16	0.1225	0.394	\$0.048	
17	0.1275	0.371	\$0.047	
18	0.135	0.350	\$0.047	\$0.44

D.4 FORCED COMBUSTION/DRAFT FANS

The lifetime and cost values shown in Table D.1 for "Combustion Fan" are taken directly from the survey described above. The primary failure mode for fans was assumed to be bearing failure. One surveyed maintenance contractor stated that fan motors, fan capacitors, and fan relays also fail, but that these account for less than about 5% of fan failures.

Engineering personnel at some fan-manufacturing companies were contacted to obtain alternative lifetime values to the survey value. However, the fan manufacturers contacted did not provide lifetime measurements specifically for furnaces. They were able to provide curves of bearing lifetime versus temperature, but usage of this data would have required testing to

establish both bearing temperature and actual hours of operation per year (or per furnace lifetime).

D.5 CONDENSING FURNACE MAINTENANCE

The maintenance contractors that responded to questions about condensing furnace maintenance cited a number of causes for maintenance calls, including sensor orifice clogging, circuit board failure, pressure switch failure, and dirt fouling of the secondary heat exchangers. The cleaning of coils and sensors were the most common causes of maintenance calls. The average of cost and lifetime values for all causes reported are shown in Table D.1 under "Condensing Design."

D.6 COMBUSTION BOX DAMPERS

Among the survey respondents, there was no maintenance experience with combustion box air dampers at the time that this investigation was performed. Therefore, a maintenance cost was estimated. The main components assumed for the damper were the mechanical damper itself, the damper motor, and a limit switch. The most likely components to fail were presumed to be the motor and the limit switch. Service lifetime was estimated at 10 years, and a maintenance call (based on San Francisco area costs) was estimated to have a \$75 labor charge (which was the average minimum labor cost cited by the surveyed contractors) and a \$12 parts cost.

D.7 TWO-STAGE OPERATION AND FULL MODULATION

No data were available on maintenance costs for these two options. Given the lack of data, the values shown in Table D.1 were estimated. For two-stage operations, incremental maintenance requirements were assumed to arise solely from control components necessary to the implementation of two-stage operations, and the maintenance costs for these control components were estimated in Table D.1 as 40% of the IID costs. Thus, two costs are shown for two-stage maintenance costs, one for 15-year lifetime equipment (e.g., direct heating equipment) and one for 18-year or longer lifetime equipment (e.g., mobile home furnaces).

For full or continuous modulation, incremental maintenance costs were also attributed to control components. The costs in Table D.1 were estimated at two times the incremental cost of maintenance for two-stage furnaces.

APPENDIX E. ELECTRIC UTILITY IMPACT MODELING

E.1 INTRODUCTION

This appendix summarizes the methodology used to calculate utility avoided costs for energy savings that result from the imposition of appliance efficiency standards. The second section explains the conventions and background information used in the analysis, and the third and fourth sections explain the basis for valuing the energy and reliability savings of the standards. The goal of this analysis is to calculate avoided costs, in dollars per million Btu (MMBtu) of electricity saved, that can be used to value electricity savings from the societal perspective. These avoided costs contain both the marginal energy and marginal reliability value of one MMBtu saved by the proposed standards in each year of the period analyzed.

E.2 BACKGROUND AND CONVENTIONS

The analysis adopts the standard utility convention that the value of electricity savings can be separated into energy (or marginal cost) savings, reliability (or capacity) savings, and transmission distribution capital cost savings. The energy impact measures the production costs avoided by reduced electrical demands, valued at the marginal energy costs of the utility (plus variable operation and maintenance costs). The reliability impact measures the reliability value of reduced load during system peak periods, which is, by convention, valued at the capital cost of a combustion turbine.

This analysis relies on disaggregation by National Electric Reliability Council (NERC) region of capacity savings and energy savings, and on re-aggregation to the national level. Disaggregation is necessary because different regions need capacity at different times, and the relative energy savings attributable to each region for heating, cooling, and all other appliances vary substantially. For the purposes of calculating utility avoided costs, heating appliances are defined as electric heat pumps and electric resistance heat, cooling appliances are defined as room and central air-conditioning plus heat pumps, and baseload appliances are defined as all other appliances affected by standards.

Regional variation in energy consumption and peak demand is accounted for by use of energy savings fractions, which are a relative measure of heating, cooling, and "baseload" energy consumption (and hence energy savings) attributable to each region. Calculating these fractions requires regional information on appliance saturations, relative appliance efficiencies, number of households, and heating and cooling load hours (25,26,27). This approach assumes that energy savings accrue in proportion to current levels of energy consumption.

Most of the information used to calculate the energy savings fractions (ESFs) is contained in Tables E.1 and E.2. The Heating Load Hours (HLH) and Cooling Load Hours (CLH) are calculated as population-weighted averages of state-level data. Alaska and Hawaii are not included in this analysis because these states are such a small fraction of the country and because they are not connected to the NERC regions in any significant way. Room CLH and Central CLH are weighted by 1980 regional saturations to derive an average CLH for each region.

Table E.1 Regional Appliance Saturations (in Fraction of Total)

NERC Region	Households	Central Air ^a	Room Air	Heat Pump Heating	Electric Resistance
NPCC	11,328,877	0.008	0.045	0.001	0.009
MAAC	9,259,883	0.021	0.040	0.002	0.008
ECAR	11,686,342	0.028	0.033	0.004	0.012
MAIN	7,042,024	0.020	0.025	0.001	0.005
SPP	6,039,959	0.027	0.024	0.002	0.009
SERC	15,379,811	0.078	0.055	0.017	0.044
ERCOT	5,485,273	0.031	0.020	0.002	0.013
MAPP	3,792,833	0.011	0.012	0.001	0.003
WSCC	16,357,454	0.043	0.025	0.006	0.030
Alaska & Hawaii	475,103	0.000	0.000	0.000	0.000
National Total	86,847,558	0.267	0.281	0.036	0.132

(a) Includes heat pumps

Table E.2 Regional Population-Weighted Heating and Cooling Load Hours

NERC Region	HLH	Central Air CLH	Room Air CLH	Saturation Weighted CLH
NPCC	2506	437	324	342
MAAC	2358	600	448	499
ECAR	2404	573	479	522
MAIN	2322	583	467	519
SPP	1646	1061	984	1024
SERC	1378	1276	964	1147
ERCOT	1250	1500	1250	1403
MAPP	2604	509	449	477
WSCC	2408	501	408	466
Alaska and Hawaii	1126	1170	1170	1170
National Average	2101	763	613	686

Table E.3 Regional Energy Savings Fractions

NERC Region	Heating	Cooling	Baseload
NPCC	0.073	0.049	0.131
MAAC	0.055	0.064	0.107
ECAR	0.110	0.083	0.135
MAIN	0.026	0.037	0.082
SPP	0.027	0.069	0.070
SERC	0.314	0.498	0.178
ERCOT	0.026	0.083	0.064
MAPP	0.009	0.009	0.044
WSCC	0.359	0.109	0.189
Total	1.000	1.000	1.000

The equations used to derive the energy savings fractions (ESFs) in Table E.3 are:

$$ESF_{Htg} = \frac{HH_i \times \left(\frac{SatHP_i}{EffHP} + \frac{SatER_i}{EffER} \right) \times HLH_i}{\sum_{i=1}^N \left[HH_i \times \left(\frac{SatHP_i}{EffHP} + \frac{SatER_i}{EffER} \right) \times HLH_i \right]}$$

$$ESF_{Clg} = \frac{HH_i \times \left(\frac{Sat (HP_i = CAC_i) \times CAC \ CLH_i}{EffCAC} + \frac{SatRAC_i \times RAC \ CLH_i}{EffRAC} \right)}{\sum_{i=1}^N \left[HH_i \times \left(\frac{Sat (HP_i + CAC_i) \times CAC \ CLH_i}{EffCAC} + \frac{SatRAC_i \times RAC \ CLH_i}{EffRAC} \right) \right]}$$

where:

HH_i	= number of households in region i (1980),
$SatER_i$	= saturation of electric resistance (ER) heat in region i (1980),
$SatHP_i$	= saturation of heat pumps (HP) in region i (1980),
$Sat(HP_i + CAC_i)$	= saturation of HPs plus central air conditioners (CAC) in region i (1980),
$SatRAC_i$	= saturation of room air conditioners (RAC) in region i (1980),
HLH_i	= heating load hours in region i,
$CAC\ CLH_i$	= cooling load hours for CACs in region i,
$RAC\ CLH_i$	= cooling load hours for RACs in region i,
N	= number of NERC regions (9),
$EffER$	= efficiency of electric resistance heat (1.0),
$EffHP$	= efficiency of average heat pump in 1980 for heating (1.75),
$EffCAC$	= efficiency of average CAC and HP cooling in 1980 (7.79 SEER), and
$EffRAC$	= efficiency of average RAC in 1980 (6.05 EER).

E.3 ENERGY SAVINGS

The energy value of load shape modifications is measured by the marginal cost of electricity, which depends on the variable cost of operating the power plants that will change their output in response to a change in load. This variable cost consists primarily of the cost of fuel for these marginal units. U.S. utilities are characterized by a substantial difference among the prices of fuels used to generate electricity on the margin. Marginal resources of a utility can be either more expensive oil and gas or less expensive non-oil-and-gas resources (typically coal). Very low variable-cost nuclear or hydro resources are usually base loaded and thus only rarely contribute to marginal energy costs. The relevant marginal cost is the cost of each marginal fuel weighted by the fraction of time each fuel is on the margin plus any variable Operation and Maintenance (O & M). Formally, this relationship can be simplified as follows:

$$\text{Marginal Cost} = OGF_m \times \text{Natural Gas Price} + NOGF_m \times \text{Coal Price} + \text{Variable O\&M}$$

To calculate the oil-and-gas fraction on the margin OGF_m , the total amount of oil and gas generated electricity is divided by the total forecasted amount of electricity generation from NERC data (28) to obtain the "total oil and gas fraction" OGF_t . OGF_t can then be related to OGF_m with a simplified load duration curve (LDC) for each region. Figure G.1 shows this LDC, where B' is the OGF_m . The non-oil-and-gas fraction $NOGF_m$ is simply $1 - OGF_m$.

The purpose of the following derivation is to calculate the OGF_m (B'). First, note that

$$\tan\Omega = \frac{A}{B}$$

and $B = 1.0$, which implies that

$$A = B \tan \Omega = \tan \Omega$$

The normalized area of the triangle at the top of the LDC represents the fraction of total generation from oil and gas (OGF_t). Calculating the area of this triangle yields

$$OGF_t = 0.5 A' B' = 0.5 (B \Omega) B'$$

B' can thus be expressed as follows:

$$B' = OGF_m = \frac{2 OGF_t^{1/2}}{(\tan \Omega)}$$

Simplified Load Duration Curve

Figure E.1 Simplified Load-Duration Curve

The appropriate value for $A = \tan \Omega$ is determined empirically: when $OGF_t \geq 0.4$, $OGF_m = 1.0$. The value of A must therefore be greater than or equal to 0.8. Note that when $A = 0.8$,

$$\text{Normalized peak demand} = 1.4 \times \text{mean load}$$

and

$$\text{Normalized minimum load} = 0.6 \times \text{mean load}.$$

A weighted-average marginal energy cost is determined for each of the NERC regions using the above formulas, and a national weighted-average marginal cost for heating and baseload energy savings is calculated using the regional fuel price multipliers and energy savings fractions described above. This approach assumes that the marginal oil-and-gas fractions remain constant over the analysis period.

For cooling energy savings, the appropriate Marginal Energy Cost (MEC) will exceed the annual average MEC because the OGF_m is typically higher in summer than in winter. The annual average OGF_m is approximately 52% when calculated using the energy savings fractions for heating, cooling, and baseload energy. Cooling MECs are calculated using a national OGF_m of 60 percent to account for the seasonal differences in marginal fuel usage. Table E.4 shows the annual average OGF_m for each NERC region.

Table E.4 Utility Marginal OGFs, and Year of Capacity Need by NERC Region

NERC Region	Marginal OGF	Year Capacity is Needed
NPCC	0.88	1992
MAAC	0.61	1992
ECAR	0.16	1992
MAIN	0.19	1992
SPP	0.77	1999
SERC	0.47	1992
ERCOT	0.92	1999
MAPP	0.15	1997
WSCC	0.55	1999
National Avg.	0.52	

The calculation of MECs in year j can be summarized as follows:

$$OGF_m = \sum_{i=1}^N ESF_i \times OGF_m^i$$

$$NOGF_m = 1 - OGF_m$$

$$MEC_j = (OGF_m \times \text{gas price}_j + NOGF_m \times \text{coal price} + \text{Variable O\&M}) \times 1.06$$

where:

i denotes a particular NERC region,

ESF_i represents the Energy Savings Fraction for region i , and

1.06 adjusts for transmission and distribution losses.

Variable O & M is calculated using references (27) and (28). Average O & M (fixed and variable) for all fossil-fuel fired steam-electric powerplants for investor-owned utilities in 1990 is reported in (30) as 0.5¢/kWh (in 1990 dollars). This can be split into fixed and variable components using (27). The analysis uses the fraction of O & M that is variable for a supercritical coal steam unit (50%) and for a natural gas Combustion Turbine (20%), weights these by the appropriate marginal oil and gas fractions, and applies the resulting percentage (variable O & M as a percent of total O & M) to the total O & M (0.5¢/kWh). This calculation results in a variable O & M cost of 0.33¢/kWh or 0.29 \$/MMBtu of resource energy (in 1990 dollars).

E.4 Reliability Savings and Avoided Transmission/Distribution System Capital Costs

E.4.1 Value of Reliability Savings

The value of reliability is the value associated with having additional generating capacity available to meet the load in case of unexpected generator outages or load increases. For utility systems with excess capacity, this value may be equal to zero. When capacity does have value, this value is commonly measured by the cost of the marginal investment a utility would make to enhance system reliability, such as the purchase of a combustion turbine (29).

The intuitive justification for this convention is that the lowest capital cost investment a utility can make to improve system reliability is a combustion turbine. This investment adds reliability to the system *even if it never operates*, since it is ready to prevent outages if another generating unit fails. If the utility chooses to build another type of plant with higher capital costs (such as a baseload coal unit), it must be basing this choice on other considerations than reliability. Baseload coal plants, for example, have much lower operating costs than oil and gas fired generation, and can be used to displace generators with higher variable cost per kWh. The additional capital cost of a coal plant is thus not related to reliability but to energy benefits or fuel savings (29).

The additional coal plant capital cost (sometimes called energy-related capital) is contained implicitly in the marginal energy cost described above. Consider a utility with a large number of expensive oil and gas units on the margin and dwindling adjusted reserves. Such a utility would need capacity to preserve the system's reliability at an acceptable level. It would also benefit from installing a baseload unit that would reduce oil and gas consumption at the margin. This reduction in fuel costs is the incentive for expending capital in addition to the costs of a combustion turbine. A utility with coal on the margin a large fraction of the time would not have the same incentive, and would probably install a combustion turbine to preserve reliability.

The utility will choose to have a baseload plant come on line when the present value of the energy-related capital cost of the plant is just equal to the PV of the reduction in fuel costs from the operation of the plant. The reduction in fuel costs and hence the incentive to build a

baseload plant depend on the marginal oil and gas fraction. Thus, the marginal energy cost contains an avoided capital component in addition to an avoided fuel component.

The following two rules are applied to determine the value of capacity for the years 1996 to 1998 based on the DOE's interpretation of NERC data (32):

1. If the NERC region is forecast to have an adjusted reserve margin larger than 5% of forecasted peak demand, there is no reliability value for capacity.¹⁸
2. If the NERC region is forecast to have a capacity deficiency (operating adjusted reserves of less than 5 %), the capacity value for the combustion turbine is applied.

After 1998, DOE has not calculated adjusted reserve margins, and it is assumed that every region will need capacity. Table G.4 shows the year that each region will need capacity based on these rules.

The calculations in this analysis follow standard industry practice developed for determining the value of reductions in peak load caused by cogenerators and other small power producers (5). First, the present value of revenue requirements is calculated for a combustion turbine based on its capital cost (\$400 per kW in 1987 dollars), a discount rate equal to the utility rate of disadvantage or ROD (10.0%), a fixed charge rate (15.2%),¹⁹ a turbine lifetime of 25 years, and the assumption of straight-line depreciation. The calculation is repeated for each year of the analysis assuming no real capital cost escalation for the combustion turbine. Next, the present values are spread over time using an economic carrying charge (ECC). The ECC technique yields a current dollar stream of costs (escalating at an inflation rate of 5%) that has the same present value (when discounted at the ROD) as the original stream. A stream of costs that escalates at the inflation rate is also constant in real terms, so this technique "levelizes" the costs to some constant dollar value (\$47.07 per kW-yr in 1990 dollars). This cost is then converted to dollars per MMBtu of electricity savings by the method detailed in the next section.

¹⁸An equivalent rule of thumb for adequate reliability is that the overall reserve margin should equal about 20% of forecasted peak demand. *Adjusted reserves* are defined by DOE as [Planned Capacity + Net Power Transfers(in) - (Forced Outages + Scheduled Maintenance + Other Outages) - Forecasted Peak Demand]. *Overall reserves* are defined as [Planned Capacity + Net Power Transfers(in) - Forecasted Peak Demand] (6). This analysis does not account for the possibility that the standards could cause a significant change in a region's adjusted reserves, and hence change the date when capacity is needed.

¹⁹The estimates of ROD and fixed charge rate have been calculated based on current interest rates and the corporate tax rate (34%) adopted in the 1986 tax revisions. The standard utility capital structure from EPRI (28) is used (45% debt, 10% preferred stock, and 10% common stock). Nominal costs of capital are 10% for debt and preferred stock and 13.4% for common stock.

E.4.2 Amount of Reliability Savings

An analysis of the load shape impacts of improved efficiencies for residential appliances must consider both the magnitude and timing of the impacts relative to periods of high system loads because residential class load shape changes only have reliability value for the system when they coincide with times of high system loads. This relationship is approximated from modeling runs of the LBL Hourly and Peak Demand Model and two LBL utility case studies (33,34).

There are large but varying degrees of coincidence between residential peak loads and system peak loads. The case studies show that the average change in the 250 highest residential hourly loads is a reasonable measure of the system-level reliability value of appliance standards.

The results of these studies also indicated that load shape impacts, measured as a conservation load factor (CLF), vary in a predictable fashion across utility service territories. A conservation load factor is the annual average load savings divided by the peak savings of the conservation measure. Peak savings are defined as the forecasted differences between the average of the highest 250 hourly loads before and after the appliance efficiency standards are implemented. The peak savings for residential appliances are calculated using the LBL Residential Hourly and Peak Demand Model (35). Peak savings for commercial ballasts are calculated using the COMMEND model's output.

Conservation load factors can be used to characterize the peak load impacts of heating, cooling, and baseload energy savings. More formally, a conservation load factor can be expressed as:

$$\text{CLF} = \frac{\text{Annual Load Savings}}{\text{Peak Load Savings}}$$

Multiplying both numerator and denominator by 8760 hours gives:

$$\text{CLF} = \frac{\text{Annual Energy Savings}}{\text{Peak Load Savings} \times 8760}$$

The peak load savings can be expressed as a function of the annual energy savings and the CLF:

$$\text{Peak Load Savings} = \frac{\text{Annual Energy Savings}}{\text{CLF} \times 8760}$$

Another useful form of this equation is as follows:

$$\text{CLF} \times 8760 = \frac{\text{Annual Energy Savings}}{\text{Peak Load Savings}}$$

CLF x 8760 = kWh of energy savings needed to yeild 1 kW of peak load savings.

Conservation load factors for the electrical appliances in this analysis are shown in Table G.5. CLFs for cooking, RAC and water heating are taken from runs of LBL's Hourly and Peak Demand Model. CLFs for fluorescent ballasts are taken from runs of EPRI's COMMEND model.

The CLF for TVs for a given policy case is calculated as a weighted average over the percentage of energy savings that is from reducing standby losses (which has a CLF of 1.0) and the percentage of energy savings that is from increasing the efficiency of the TV when it is being used (which has a CLF of 0.86, from reference (36)).

The load impacts of the heating energy savings are excluded because NERC data and forecasts suggest that all NERC regions will have lower adjusted reserve margins in summer than in winter through 1998; therefore, to a rough approximation, energy savings only have reliability value in summer.²⁰ As a consequence of this assumption, the indirect effects on electricity use of standards on gas-fired mobile home furnaces and gas-fired direct heating equipment are valued using avoided costs that include only the avoided energy and O&M costs. There is no capacity component to the avoided costs for these end uses.

²⁰This approach implicitly assumes that transmission capacity within each region allows most efficient utilization of the region's generating capacity. The analysis does not account for the possibility that the efficiency standards could cause regions to shift from summer to winter peaking.

Table E.5 Conservation Load Factors for Electrical Products

Appliance/Product	CLF
RAC	0.14
Water heating	0.89
Cooktops/ovens/microwaves	0.46
TVs policy 1 (standby energy use)	1.00
Other TV policies (not standby)	0.86
Fluorescent ballasts	0.57

The calculation of avoided reliability costs can be summarized in the following equations:

$$ARC_{Clg,j} = \frac{\text{Capacity Value}}{CLF_{cooling} \times 8760} \times \frac{1 \text{ kWh}}{11,500 \text{ Btu}} \times \frac{10^6}{\text{MMBtu}} \times 1.2 \times \Sigma ESF_{Clg,j}$$

$$ARC_{Baseload,j} = \frac{\text{Capacity Value}}{CLF_{Baseload} \times 8760} \times \frac{1 \text{ kWh}}{11,500 \text{ Btu}} \times \frac{10^6}{\text{MMBtu}} \times 1.2 \times \Sigma ESF_{Baseload,j}$$

where:

$ARC_{Clg,Baseload,j}$ = Avoided reliability costs in 1990 \$/MMBtu in year j,

Capacity Value = value of 1 kW of peak load savings in (1990 \$/kW-yr),

11,500 Btu/kWh = conversion factor that includes generation and transmission losses,

$CLF_{Baseload}$ = conservation load factor for baseload appliances,

$\Sigma ESF_{Clg,j}$ = sum of cooling ESFs for regions that need capacity in year j,

$\Sigma ESF_{Baseload,j}$ = sum of baseload ESFs for regions that need capacity in year j, and

1.2 = reserve margin adjustment needed for adequate reliability.

Capacity savings are peak load savings for only those regions that need capacity in a given year. Load savings in regions that do not need capacity contribute to deferring capacity additions in future years, but this analysis does not account for the value of such deferrals.

Table E.6 Sums of AC and Baseload Energy Savings Fractions for NERC Regions That Need Capacity

Year	Cooling ESF	Baseload ESF	Regions Needing Capacity
1996	0.693	0.552	5
1997	1.703	0.552	6
1998	0.703	0.596	6
1999	1.000	1.000	9
2000	1.000	1.000	9

E.4.3 Avoided Transmission and Distribution Capital Costs

Recently, utility planners have begun to account for capital costs of the Transmission and Distribution (T & D) System that can be avoided by reductions in electricity use. There are a wide range of estimates of such costs, depending on the particular characteristics of the utility system and of the conservation programs that lead to such reductions in electricity use. Krause et al. (37) review the most recent studies on this topic, and settle on a range for T & D savings of from \$10 to \$40/kW-yr. Krause et al. also cite reasons why this range is probably too low, and suggest that further work will probably raise these values. For example, they cite marginal T & D cost estimates of nine different utilities that (on average) totaled more than \$100/kW-yr.

We adopt the lower end of Krause et al.'s range (\$10/kW-yr) as our estimate for avoided T & D capital costs. We choose this lower bound estimate because of the substantial uncertainties in applying such estimates (which are derived at the level of individual utilities) in national analyses.

E.5 RESULTS

Tables E.7 and E.8 show base case avoided energy and reliability costs (respectively) for electricity savings from the analyzed end-uses. Tables E.9 through E.11 show the sum of avoided costs for the base-, high-, and low-energy-price cases.

Table E.7 Electric Utility Avoided Energy Costs: Base Case (Dollars per MMBtu of Resource Energy Saved)

Year	Avoided Energy Cost: Heating	Avoided Energy Cost: Cooling	Avoided Energy Cost: Baseload
1990	2.488	2.650	2.486
1991	2.654	2.842	2.655
1992	2.836	3.052	2.838
1993	3.035	3.281	3.039
1994	3.252	3.533	3.259
1995	3.490	3.808	3.498
1996	3.622	3.962	3.632
1997	3.761	4.124	3.773
1998	3.907	4.294	3.920
1999	4.060	4.473	4.075
2000	4.221	4.661	4.238
2001	4.389	4.858	4.409
2002	4.567	5.066	4.588
2003	4.753	5.284	4.776
2004	4.949	5.512	4.974
2005	5.154	5.753	5.182
2006	5.370	6.006	5.400
2007	5.596	6.271	5.630
2008	5.834	6.550	5.871
2009	6.085	6.843	6.124
2010	6.347	7.152	6.390
2011	6.624	7.476	6.669
2012	6.914	7.816	6.963
2013	7.219	8.174	7.272
2014	7.539	8.550	7.596
2015	7.876	8.946	7.937

Table E.8 Electric Utility Avoided Reliability Costs (Dollars per MMBtu of Resource Energy Saved)

Year	Avoided Reliability Cost: Heating	Avoided Reliability Cost: Cooling	Avoided Reliability Cost: Baseload
1990	0.000	0.270	0.049
1991	0.000	0.421	0.086
1992	0.000	0.421	0.086
1993	0.000	1.516	0.247
1994	0.000	1.793	0.309
1995	0.000	1.793	0.308
1996	0.000	2.436	0.457
1997	0.000	2.436	0.457
1998	0.000	2.436	0.457
1999	0.000	2.436	0.457
2000	0.000	2.436	0.457
2001	0.000	2.436	0.457
2002	0.000	2.436	0.457
2003	0.000	2.436	0.457
2004	0.000	2.436	0.457
2005	0.000	2.436	0.457
2006	0.000	2.436	0.457
2007	0.000	2.436	0.457
2008	0.000	2.436	0.457
2009	0.000	2.436	0.457
2010	0.000	2.436	0.457
2011	0.000	2.436	0.457
2012	0.000	2.436	0.457
2013	0.000	2.436	0.457
2014	0.000	2.436	0.457
2015	0.000	2.436	0.457

Table E.9 Total Utility Avoided Costs: Base Case (Dollars per MMBtu of Resource Energy Saved)

Year	Total Avoided Cost: Heating	Total Avoided Cost: Cooling	Total Avoided Cost: Baseload
1990	2.488	2.920	2.535
1991	2.654	3.263	2.741
1992	2.836	3.473	2.925
1993	3.035	4.797	3.287
1994	3.252	5.326	3.568
1995	3.490	5.601	3.806
1996	3.622	6.398	4.089
1997	3.761	6.560	4.229
1998	3.907	6.730	4.377
1999	4.060	6.909	4.532
2000	4.221	7.097	4.694
2001	4.389	7.294	4.865
2002	4.567	7.502	5.045
2003	4.753	7.720	5.233
2004	4.949	7.948	5.431
2005	5.154	8.189	5.639
2006	5.370	8.442	5.857
2007	5.596	8.707	6.086
2008	5.834	8.986	6.327
2009	6.085	9.279	6.580
2010	6.347	9.588	6.846
2011	6.624	9.912	7.126
2012	6.914	10.252	7.420
2013	7.219	10.610	7.728
2014	7.539	10.986	8.053
2015	7.876	11.382	8.394

Table E.10 Total Utility Avoided Costs: High Price Case (Dollars per MMBtu of Resource Energy Saved)

Year	Total Avoided Cost: Heating	Total Avoided Cost: Cooling	Total Avoided Cost: Baseload
1990	2.531	2.972	2.579
1991	2.708	3.327	2.795
1992	2.902	3.551	2.991
1993	3.115	4.891	3.367
1994	3.348	5.439	3.665
1995	3.604	5.736	3.921
1996	3.825	6.638	4.295
1997	4.065	6.920	4.538
1998	4.325	7.224	4.800
1999	4.606	7.554	5.085
2000	4.911	7.912	5.394
2001	5.241	8.300	5.728
2002	5.598	8.720	6.089
2003	5.985	9.176	6.482
2004	6.405	9.669	6.907
2005	6.860	10.204	7.367
2006	7.353	10.784	7.866
2007	7.887	11.413	8.407
2008	8.467	12.095	8.994
2009	9.094	12.835	9.630
2010	9.775	13.637	10.319
2011	10.513	14.506	11.066
2012	11.313	15.449	11.877
2013	12.181	16.472	12.756
2014	13.122	17.581	13.709
2015	14.142	18.784	14.742

Table E.11 Total Utility Avoided Costs: Low Price Case (Dollars per MMBtu of Resource Energy Cost:

Year	Total Avoided Cost: Heating	Total Avoided Cost: Cooling	Total Avoided Cost: Baseload
1990	2.314	2.715	2.359
1991	2.451	3.023	2.534
1992	2.599	3.193	2.684
1993	2.759	4.471	3.007
1994	2.932	4.948	3.244
1995	3.120	5.164	3.432
1996	3.264	5.975	3.727
1997	3.418	6.154	3.882
1998	3.581	6.344	4.046
1999	3.754	6.547	4.222
2000	3.939	6.762	4.409
2001	4.135	6.992	4.607
2002	4.344	7.236	4.819
2003	4.566	7.496	5.044
2004	4.803	7.773	5.283
2005	5.055	8.069	5.538
2006	5.323	8.383	5.810
2007	5.609	8.718	6.099
2008	5.913	9.075	6.407
2009	6.237	9.455	6.735
2010	6.582	9.860	7.084
2011	6.950	10.291	7.456
2012	7.342	10.751	7.852
2013	7.759	11.241	8.275
2014	8.203	11.764	8.725
2015	8.677	12.320	9.204

ENVIRONMENTAL ASSESSMENT FOR PROPOSED ENERGY CONSERVATION STANDARDS FOR EIGHT TYPES OF CONSUMER PRODUCTS: ROOM AIR CONDITIONERS, WATER HEATERS, DIRECT HEATING EQUIPMENT, MOBILE HOME FURNACES, RANGES AND OVENS, POOL HEATERS, FLUORESCENT BALLASTS, AND TELEVISIONS

1 INTRODUCTION AND NEED FOR PROPOSED ACTION

This Environmental Assessment (EA) on the candidate energy conservation standards for eight appliances (room air conditioners, water heaters, direct heating equipment, mobile home furnaces, kitchen ranges and ovens, pool heaters, fluorescent lamp ballasts, and television sets) was prepared pursuant to the National Environmental Policy Act of 1969 (NEPA), regulations of the Council on Environmental Quality, Title 40, Code of Federal Regulations, Parts 1500 through 1508. The candidate conservation standards are being proposed pursuant to the Energy Policy and Conservation Act, as amended by the National Energy Conservation Policy Act, the National Appliance Energy Conservation Act and the National Appliance Energy Conservation Amendments.

The EA presents the results of the associated environmental impacts from a range of new candidate energy conservation standards for eight types of household appliances. The results are presented for each potential standard level for each of the eight appliance types. 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 each product were finalized, i.e., the "no action" alternative.

The main environmental concern addressed is emissions from fossil-fueled electricity generation. Most of the design options for the eight appliances result in decreased electricity use and, therefore, a reduction of 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. Carbon dioxide (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. Design options for many of the appliances (i.e. gas and oil water heaters, gas pool heaters, direct heating equipment, mobile home furnaces, and gas ranges and ovens) also reduce in-home fuel consumption, resulting in lower in-home emissions from fuel-burning appliances.

Although the quantity of raw materials used per appliance will remain relatively constant, in most scenarios increased initial cost is expected to decrease slightly the number of appliances sold, resulting in small decreases in raw materials used. The main effect of decreased appliance production is the SO₂ emitted in steel production. The decrease is small, however, in comparison to the SO₂ decreases from fuel burning avoided at power plants. The contribution from steel production is not included in the estimates for net SO₂ decreases resulting from design changes in these products.

The effects on particulate emissions related to a standard-induced decrease in electricity generation would be minor compared to effects on decreases in SO₂, NO₂, and CO₂. For example, in 1984, power plants contributed only 7% of U.S. total particulate emissions as compared to contributions of 83% and 34% to total SO₂ and NO₂ emissions, respectively ¹. Though the reduction in particulate emissions would be relatively small, any reduction would possibly be beneficial to improving the quality of surfacewater. Since the amount of particulates emitted would be decreased, it is very likely that less particulates would reach the surfacewater.

Reductions in particulate emissions accompanied by decreases in SO₂ and NO₂ would have other beneficial effects on the environment. The resultant improvement to air quality and the decreased potential of acid rain formation would help improve the quality of wetlands and fish & wildlife as well as aid in the preservation of historical and archaeological sites.

Reduced in-home fuel consumption will decrease the amount of gas or oil burned within some homes, thereby decreasing the impact of combustion on indoor air quality. Indoor air problems are usually due to a combination of factors, including a tight house envelope, insufficient ventilation for cooking appliances, presence of sources such as cigarette smokers or formaldehyde containing products, and radon diffusion from soil. In comparison to the above factors, and because fuel-burning appliances are normally vented to the outside, the projected changes in in-home fuel-burning appliance use is expected to have little effect on indoor air quality.

2 METHODS OF ESTIMATING ENVIRONMENTAL IMPACTS

The greatest impacts of the proposed standards would be a reduction in electricity demand growth. The main environmental effects of power plants on air and water quality result from emissions of sulfur dioxide (SO₂), nitrogen oxides (NO_x), and carbon dioxide (CO₂). With the proposed standards lessening the need for electricity generation, power plant emissions would be reduced. A second source of these pollutants is fuel-burning household appliances. Pollutants from fuel-burning household appliances will be termed "in-house" emissions. The proposed standards would also reduce these emissions. Since fuel-burning household appliances are normally vented to the outside, both the power plant and "in-house" emissions are reported.

2.1 Baseline Emissions

The estimates of emissions of SO₂, NO_x, and CO₂ are also expressed as a percentage of U.S. power plant emissions for the year under consideration. In a report that accompanies the 1991 National Energy Strategy (NES), the impact on power plant emissions as a result of revisions to Title V of the 1990 Clean Air Act (i.e., H.R. 3030) are estimated ².

To reduce NO_x emissions, the Clean Air Act will require utilities to add low NO_x burners to coal plants greater than 75 megawatts (nameplate). NO_x emissions are required to be reduced by 2 million tons by the year 2000 under the legislation. No emissions cap exists for NO_x, therefore, as new units are added after the year 2000, NO_x emissions will increase.

The legislation calls for SO₂ emissions reductions in two phases. In the first phase of the planned reductions (beginning December 31, 1995 and carrying through the year 2000), electric utilities will have several options for reducing their SO₂ emissions to comply with the allowance constraints imposed by the provisions of the Clean Air Act. The major options are 1) to decrease their use of high emission units and increase the use of their clean coal, gas, or oil units, 2) to switch units using high sulfur coal to low sulfur coal, 3) to retrofit plants emitting at a high rate with emissions reduction technologies (e.g., scrubbers), and 4) to purchase allowances from other utilities who reduce their emissions below their permitted levels, in order to sell their allowances for a profit. Most utilities will make use of a combination of these options to minimize the cost of complying with the allowance constraints. Total SO₂ emissions by utilities cannot exceed 8.9 million tons after December 31, 2000.

In the second phase of the planned reductions (beginning December 31, 2000), the options available to electric utilities for maintaining the 8.9 million-ton cap will broaden with the expected introduction of new, advanced generating technologies. However, during this period utilities are less able to reduce emissions by changing the way they utilize their plants. Since most plants will be fully utilized, there will be few opportunities for reducing emissions by decreasing the use of a high emission plant.

In the report accompanying the 1991 NES, two possible outcomes are presented, a flexible case and a restricted case, so that the effect of different levels of permitted trading of emission allowances can be evaluated. (The report does not go beyond this explanation in defining the differences between the two cases.) As presented in the report, the results for the two cases are virtually identical. Because the two cases are so similar, the U.S. power plant emission projections for the three effluents under the assumptions made in the flexible case are presented only. Table 1 summarizes the results.

Table 1 U.S. CO₂, SO₂, NO_x Power Plant Emissions

Year	CO ₂ 10 ⁶ tons	SO ₂ 10 ⁶ tons	NO _x 10 ⁶ tons
1995	2232.5	13.8	8.4
2000	2506.2	9.0	6.7
2010	3219.3	8.4	7.3
2020	3964.2	6.7	6.7
2030	4804.4	4.8	5.9

2.2 Sulfur and Nitrogen Oxide Emissions

For each of the scenarios analyzed, emissions abated from fossil fuel-burning power plants are estimated. In analyzing the impacts of design changes to each of the appliances, lower sulfur emissions resulting from decreased steel production are not considered. No changes in the amount of steel used per unit are expected. Analysis of the impacts resulting from several design options includes the consideration of SO₂ and NO_x from in-home combustion of gas and oil.

In order to capture the effects of cleaner-burning power plants in future years, emission rates (tons/Quad) for power plant fuel-burning are calculated from projected emissions and electrical generation data. The electrical generation data is translated into energy use (Quads) by multiplying the generation data by 11,500 Btu/kWh. The source of these projected emissions and electrical generation data is the report that accompanies the 1991 National Energy Strategy (data for Table 1 was extracted from the same Service Report). (2) Table 2 presents these data and the calculated emission rates for SO₂ and NO_x.

Table 2 Electrical Generation and Emissions Data and Emission Rates for SO₂ and NO_x at Fossil Fuel-Burning Power Plants

Year	Electrical Generation			Energy Use Total Quads	Emissions		Emissions Rates	
	Coal 10 ⁹ kWh	Oil 10 ⁹ kWh	Gas 10 ⁹ kWh		SO ₂ 10 ⁶ tons	NO _x 10 ⁶ tons	SO ₂ 10 ³ tons/Quad	NO _x 10 ³ tons/Quad
1995	1602.2	193.7	442.0	25.74	13.8	8.4	552.5	336.3
2000	1814.0	179.8	605.0	29.89	9.0	6.7	310.3	231.0
2010	2660.6	149.9	482.5	37.88	8.4	7.3	228.6	198.6
2020	3727.8	67.2	292.3	47.01	6.7	6.7	146.9	146.9
2030	4837.3	29.0	179.2	58.03	4.8	5.9	85.2	104.8

The calculated emissions rate data listed in Table 2 represent the average SO₂ and NO_x emissions rates for all fossil fuel-burning power plants in the United States. Emissions rates were not calculated for each fuel-burning source as the emissions data supplied by the Service Report

were not disaggregated according to power plant type (i.e. coal, oil, gas). To obtain emission rate values, the amount of emissions were divided by the total energy use of fossil fuel-burning power plants. The total energy use by fossil fuel-burning power plants was calculated from the electrical generation data supplied by the report accompanying the 1991 NES. The electrical generation data was disaggregated by fuel source. To obtain the total energy use (input), the electrical generation data from each fossil fuel source was summed and then divided by the assumed efficiency of fossil fuel-burning power plants (30.6%). This fossil fuel-burning power plant efficiency is consistent with that used by the LBL Residential Energy Model (REM). For further information on the assumed efficiency of fossil fuel-burning power plants, refer to Appendix B of volume A of the Technical Support Document (TSD).

The amount of SO₂ and NO_x emissions abated for any particular year is determined by multiplying the estimates of energy saved through reduced electricity generation in that year by the emission rate for that particular year. For years not covered in the Service Report, linear interpolation was used to derive emission rates and, in turn, the corresponding abated emissions.

Table 3 presents the emission factors (rates) that were used for SO₂ and NO_x for in-home gas and oil combustion. The values for reduction of SO₂ and NO_x emissions from in-home gas and oil combustion are produced by multiplying in-home fuel savings for gas and oil by the corresponding emission rates. Emission factors that appear in Table 3 are from a Lawrence Berkeley Laboratory report. (3) Emission factors for gas in-home combustion were assumed to equal the average of those for residential gas space heaters and water heaters. Emission factors for oil in-home combustion were assumed to equal those associated with a residential #2 oil boiler.

Table 3 Emission Rates for SO₂ and NO_x for In-Home Combustion

SO ₂ Gas Emission <i>10³ tons/Quad</i>	SO ₂ Oil Emission <i>10³ tons/Quad</i>	NO _x Gas Emission <i>10³ tons/Quad</i>	NO _x Oil Emission <i>10³ tons/Quad</i>
0.0	156.5	52.5	65.0

2.3 Carbon Dioxide Emissions

Emission rates for carbon dioxide were derived in the same manner as those derived for SO₂ and NO_x. As presented in Table 1, the report accompanying the 1991 National Energy Strategy (NES) also provided emissions data with regard to CO₂.¹ Table 4 presents the CO₂ emission rate data as derived from the electrical generation data and emissions data supplied by the 1991 NES report.

¹ Upon phone conversations with David Streets at Argonne National Laboratory (February 1992), it was determined that the carbon emissions data provided in the report accompanying the 1991 NES were mistakenly reported as tons of carbon emitted. David Streets was one of authors at Argonne who contributed to the 1991 NES report.

Table 4 Electrical Generation Data, Emissions Data and Emissions Rates for CO₂ at Fossil Fuel-Burning Power Plants

Year	Electrical Generation			Energy Use Total <i>Quads</i>	Emission CO ₂ <i>10⁶ tons</i>	Emission Rate CO ₂ <i>10⁶ tons/Quad</i>
	Coal <i>10⁹ kWh</i>	Oil <i>10⁹ kWh</i>	Gas <i>10⁹ kWh</i>			
1995	1602.2	193.7	442.0	25.74	2232.5	89.39
2000	1814.0	179.8	605.0	29.89	2506.2	86.41
2010	2660.6	149.9	482.5	37.88	3219.3	87.60
2020	3727.8	67.2	292.3	47.01	3964.2	86.90
2030	4837.3	29.0	179.2	58.03	4804.4	85.32

As with the SO₂ and NO_x emissions, the amount of CO₂ emissions abated for any particular year is determined by multiplying the estimates of energy saved through reduced electricity generation by the emission rate for that particular year. For years not covered in the Service Report, linear interpolation was used to derive emission rates and, in turn, the corresponding abated emissions.

Table 5 presents the emission factors (rates) that were used for CO₂ for in-home gas and oil combustion. The values for the reduction of CO₂ emissions from in-home gas and oil combustion are produced by multiplying in-home fuel savings for gas and oil by the corresponding emission rates. Emission factors that appear in Table 5 are from a Lawrence Berkeley Laboratory report³. The emission factor for gas in-home combustion was assumed to equal the average of those for residential gas space heaters and water heaters. The emission factor for oil in-home combustion was assumed to equal the one associated with a residential #2 oil boiler.

Table 5 Emission Rates for CO₂ for In-Home Combustion

CO ₂ Gas Emission <i>10³ tons/Quad</i>	CO ₂ Oil Emission <i>10³ tons/Quad</i>
55,000	84,300

3 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 each of the eight appliances considered in this analysis. A table is presented for each of the appliances' trial standard 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. CO₂, SO₂, and NO_x) through the imposition of an appliance's 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).

For each section that follows, only the results from the last standard level are discussed for each appliance. In order to view the results for each standard level, tables for each level are provided after the discussion.

It should be noted that the standard levels studied for each appliance are not consistent between the eight appliances. The number of standard levels that are analyzed for a particular appliance depends on the number and type of technologies that were considered for it. For a detailed explanation of the specific technologies considered for each appliance, please refer to the appropriate sections and appendices of the Technical Support Document.

3.1 ROOM AIR CONDITIONERS

Decreases in the amounts of CO₂, SO₂, and NO_x emitted at trial standards levels 1 through 7 are summarized in Tables 6 through 12.

3.1.1 Sulfur and Nitrogen Oxide Emissions

Sulfur dioxide 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 sulfur dioxide 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.

3.1.2 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. power plant 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. power plant CO₂ emissions in 2030.

Table 6
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
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 8
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 9
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 10
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 11
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 12
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

3.2 WATER HEATERS

Decreases in the amounts of CO₂, SO₂, and NO_x emitted at trial standards levels 1 through 8 are summarized in Tables 13 through 20.

3.2.1 Sulfur and Nitrogen Oxide Emissions

Sulfur dioxide emissions would be decreased by a cumulative total of up to 7.12 million tons between 1996 and 2030 in the level 8 scenario. In the year 1996, decreases in sulfur dioxide will represent about 1.14% of the SO₂ emissions estimated to come from power plants in that year. In the year 2030, decreases in SO₂ emissions will represent about 2.44% of the SO₂ emissions estimated to come from power plants in that year. As discussed earlier, 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 8 design changes to water heaters would result in an estimated decrease in NO_x emissions of 7.11 million tons between 1996 and 2030. NO_x decreases would represent 1.21% and 2.81% of the NO_x emissions estimated to come from power plants in the years 1996 and 2030, respectively.

3.2.2 Carbon Dioxide Emissions

The cumulative reduction in CO₂ emissions from level 8 design changes is 4113 million tons of CO₂. For the year 1996, the estimated CO₂ reduction is 33,450 thousand tons of CO₂ or about 1.46% of estimated U.S. power plant CO₂ emissions in 1996. For the year 2030, the estimated CO₂ reduction is 142,630 thousand tons of CO₂ or about 2.97% of estimated U.S. power plant CO₂ emissions in 2030.

Table 13
Reduction of Pollutants for Water Heaters - 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	0	86	0.00%
2000	252	0	252	0.01%
2005	338	139	477	0.02%
2010	170	0	170	0.01%
2015	85	0	85	0.00%
2020	169	55	224	0.01%
2025	83	55	138	0.00%
2030	166	0	166	0.00%

Cumulative CO2 reduction, 1996-2030 = 7 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	903	0	903	0.01%
2005	1,027	157	1,184	0.01%
2010	444	0	444	0.01%
2015	178	0	178	0.00%
2020	285	0	285	0.00%
2025	109	0	109	0.00%
2030	165	0	165	0.00%

Cumulative SO2 reduction, 1996-2030 = 16,662 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	0	303	0.00%
2000	672	0	672	0.01%
2005	826	117	944	0.01%
2010	385	0	385	0.01%
2015	165	0	165	0.00%
2020	285	52	338	0.01%
2025	120	53	172	0.00%
2030	203	0	203	0.00%

Cumulative NOx reduction, 1996-2030 = 14,405 tons

Table 14
Reduction of Pollutants for Water Heaters - 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	689	84	773	0.03%
2000	1,845	224	2,068	0.08%
2005	2,619	418	3,037	0.11%
2010	1,955	334	2,289	0.07%
2015	1,269	418	1,687	0.05%
2020	928	334	1,261	0.03%
2025	584	279	863	0.02%
2030	497	363	860	0.02%

Cumulative CO2 reduction, 1996-2030 = 59 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	157	4,022	0.03%
2000	6,624	313	6,937	0.08%
2005	7,960	470	8,429	0.10%
2010	5,101	313	5,414	0.06%
2015	2,668	470	3,138	0.04%
2020	1,568	313	1,881	0.03%
2025	766	313	1,079	0.02%
2030	496	470	966	0.02%

Cumulative SO2 reduction, 1996-2030 = 145,477 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	65	2,492	0.03%
2000	4,931	182	5,114	0.08%
2005	6,404	352	6,757	0.10%
2010	4,433	287	4,720	0.06%
2015	2,474	352	2,826	0.04%
2020	1,568	287	1,855	0.03%
2025	840	235	1,075	0.02%
2030	610	300	910	0.02%

Cumulative NOx reduction, 1996-2030 = 118,434 tons

Table 15
Reduction of Pollutants for Water Heaters - 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	18,077	1,991	20,068	0.88%
2000	44,857	4,286	49,143	1.96%
2005	70,802	6,500	77,302	2.70%
2010	73,607	6,911	80,518	2.50%
2015	74,385	7,520	81,904	2.28%
2020	76,651	7,824	84,475	2.13%
2025	78,634	8,128	86,762	1.98%
2030	81,381	8,517	89,898	1.87%

Cumulative CO2 reduction, 1996-2030 = 2,607 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	101,482	939	102,421	0.80%
2000	161,086	2,035	163,120	1.81%
2005	215,169	3,287	218,455	2.51%
2010	192,061	3,130	195,191	2.32%
2015	156,360	3,443	159,803	2.10%
2020	129,550	3,600	133,149	1.99%
2025	103,128	3,756	106,884	1.84%
2030	81,306	4,069	85,375	1.78%

Cumulative SO2 reduction, 1996-2030 = 5,381,123 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	63,703	1,808	65,511	0.81%
2000	119,919	3,890	123,809	1.85%
2005	173,124	5,880	179,004	2.56%
2010	166,910	6,288	173,198	2.37%
2015	144,970	6,838	151,807	2.17%
2020	129,550	7,113	136,662	2.04%
2025	112,993	7,388	120,380	1.91%
2030	99,939	7,728	107,667	1.82%

Cumulative NOx reduction, 1996-2030 = 4,890,115 tons

Table 16
Reduction of Pollutants for Water Heaters - 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	21,263	2,156	23,418	1.02%
2000	50,139	4,645	54,784	2.19%
2005	76,885	6,775	83,660	2.92%
2010	79,727	7,270	86,997	2.70%
2015	80,732	7,850	88,581	2.47%
2020	83,312	8,154	91,466	2.31%
2025	85,563	8,598	94,160	2.15%
2030	88,666	8,986	97,652	2.03%

Cumulative CO2 reduction, 1996-2030 = 2,837 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	119,363	939	120,302	0.94%
2000	180,055	2,191	182,246	2.02%
2005	233,656	3,287	236,942	2.72%
2010	208,029	3,287	211,316	2.52%
2015	169,701	3,443	173,144	2.28%
2020	140,809	3,600	144,408	2.16%
2025	112,215	3,913	116,128	2.00%
2030	88,585	4,226	92,811	1.93%

Cumulative SO2 reduction, 1996-2030 = 5,885,240 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	74,927	1,965	76,892	0.95%
2000	134,041	4,218	138,258	2.06%
2005	187,999	6,143	194,141	2.77%
2010	180,787	6,615	187,402	2.57%
2015	157,339	7,153	164,491	2.35%
2020	140,809	7,428	148,236	2.21%
2025	122,949	7,820	130,769	2.08%
2030	108,886	8,160	117,046	1.98%

Cumulative NOx reduction, 1996-2030 = 5,337,547 tons

Table 17
Reduction of Pollutants for Water Heaters - 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	21,176	2,350	23,527	1.03%
2000	49,972	5,034	55,005	2.19%
2005	76,631	7,278	83,909	2.93%
2010	79,472	7,717	87,190	2.71%
2015	80,562	8,271	88,834	2.47%
2020	83,144	8,575	91,719	2.31%
2025	85,479	8,964	94,443	2.15%
2030	88,583	9,408	97,991	2.04%

Cumulative CO2 reduction, 1996-2030 = 2,845 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	118,879	1,096	119,975	0.94%
2000	179,453	2,504	181,957	2.02%
2005	232,885	3,913	236,798	2.72%
2010	207,364	3,913	211,276	2.52%
2015	169,346	4,226	173,571	2.28%
2020	140,524	4,382	144,906	2.16%
2025	112,106	4,695	116,801	2.01%
2030	88,502	5,008	93,510	1.95%

Cumulative SO2 reduction, 1996-2030 = 5,890,278 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	74,624	2,135	76,759	0.95%
2000	133,592	4,558	138,150	2.06%
2005	187,379	6,560	193,939	2.77%
2010	180,209	6,980	187,189	2.56%
2015	157,009	7,478	164,487	2.35%
2020	140,524	7,753	148,276	2.21%
2025	122,829	8,093	130,921	2.08%
2030	108,784	8,485	117,269	1.99%

Cumulative NOx reduction, 1996-2030 = 5,335,580 tons

Table 18
Reduction of Pollutants for Water Heaters - 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	28,063	2,211	30,274	1.32%
2000	65,986	4,205	70,191	2.80%
2005	101,218	5,620	106,838	3.73%
2010	105,906	5,785	111,692	3.47%
2015	108,235	6,284	114,519	3.19%
2020	112,067	6,588	118,655	2.99%
2025	115,530	6,977	122,507	2.79%
2030	119,960	7,475	127,436	2.65%

Cumulative CO2 reduction, 1996-2030 = 3,662 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	157,539	939	158,478	1.24%
2000	236,962	2,191	239,153	2.66%
2005	307,604	3,287	310,890	3.57%
2010	276,337	3,287	279,624	3.33%
2015	227,514	3,600	231,113	3.04%
2020	189,407	3,756	193,163	2.88%
2025	151,518	4,069	155,587	2.68%
2030	119,850	4,382	124,232	2.59%

Cumulative SO2 reduction, 1996-2030 = 7,795,782 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	98,892	2,018	100,909	1.25%
2000	176,405	3,798	180,202	2.69%
2005	247,497	5,040	252,537	3.61%
2010	240,150	5,198	245,348	3.36%
2015	210,940	5,643	216,582	3.09%
2020	189,407	5,918	195,325	2.92%
2025	166,011	6,258	172,268	2.73%
2030	147,316	6,703	154,019	2.61%

Cumulative NOx reduction, 1996-2030 = 6,995,324 tons

Table 19
Reduction of Pollutants for Water Heaters - 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	28,149	3,175	31,324	1.37%
2000	66,154	6,215	72,368	2.89%
2005	101,471	8,400	109,871	3.84%
2010	106,246	8,620	114,866	3.57%
2015	108,573	8,788	117,361	3.27%
2020	112,404	8,597	121,002	3.05%
2025	115,864	8,546	124,410	2.84%
2030	120,291	8,605	128,896	2.68%

Cumulative CO2 reduction, 1996-2030 = 3,747 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	158,023	1,096	159,118	1.24%
2000	237,564	2,348	239,911	2.67%
2005	308,374	3,443	311,817	3.58%
2010	277,224	3,443	280,667	3.34%
2015	228,225	3,756	231,981	3.05%
2020	189,978	3,913	193,890	2.89%
2025	151,956	4,226	156,181	2.69%
2030	120,181	4,539	124,720	2.60%

Cumulative SO2 reduction, 1996-2030 = 7,823,000 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	99,195	2,923	102,117	1.26%
2000	176,853	5,700	182,553	2.72%
2005	248,117	7,678	255,795	3.65%
2010	240,921	7,888	248,809	3.41%
2015	211,599	8,018	219,617	3.14%
2020	189,978	7,820	197,798	2.95%
2025	166,491	7,740	174,231	2.77%
2030	147,723	7,765	155,488	2.64%

Cumulative NOx reduction, 1996-2030 = 7,085,801 tons

Table 20
Reduction of Pollutants for Water Heaters - Level Eight

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	25,739	7,711	33,450	1.46%
2000	60,117	17,651	77,768	3.10%
2005	92,008	26,630	118,639	4.14%
2010	95,877	30,070	125,946	3.91%
2015	97,910	31,723	129,634	3.61%
2020	102,201	31,866	134,067	3.38%
2025	106,265	31,573	137,837	3.14%
2030	111,516	31,114	142,630	2.97%

Cumulative CO2 reduction, 1996-2030 = 4,113 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	144,492	939	145,431	1.14%
2000	215,885	2,035	217,920	2.42%
2005	279,617	3,287	282,903	3.25%
2010	250,167	3,443	253,610	3.02%
2015	205,812	3,756	209,568	2.76%
2020	172,733	4,226	176,958	2.64%
2025	139,366	5,008	144,374	2.49%
2030	111,414	5,791	117,204	2.44%

Cumulative SO2 reduction, 1996-2030 = 7,124,332 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	90,701	7,268	97,969	1.21%
2000	160,714	16,648	177,362	2.65%
2005	224,979	25,095	250,074	3.57%
2010	217,407	28,363	245,770	3.37%
2015	190,819	29,910	220,729	3.15%
2020	172,733	30,000	202,733	3.03%
2025	152,696	29,643	182,339	2.89%
2030	136,946	29,128	166,073	2.81%

Cumulative NOx reduction, 1996-2030 = 7,109,299 tons

3.3 DIRECT HEATING EQUIPMENT

Changes in the amount of CO₂, SO₂, and NO_x emitted at trial standards levels 1 through 5 are summarized in Tables 21 through 25.

3.3.1 Sulfur and Nitrogen Oxide Emissions

Sulfur dioxide emissions would be increased by a cumulative total of up to 0.32 million tons between 1996 and 2030 in the level 5 scenario. In the year 1996, increases in sulfur dioxide will represent about 0.04% of the SO₂ emissions estimated to come from power plants in that year. In the year 2030, increases in SO₂ emissions will represent about 0.04% of the SO₂ emissions estimated to come from power plants in that year. Although increased in the level 5 scenario, SO₂ emissions would be decreased between 1996 and 2030 in the level 1, 2, and 3 scenarios. However, as discussed earlier, 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 direct heating equipment would result in an estimated increase in NO_x emissions of 0.18 million tons between 1996 and 2030. NO_x increases would represent 0.03% and 0.01% of the NO_x emissions estimated to come from power plants in the years 1996 and 2030, respectively.

It should be noted that, although direct heating equipment consists entirely of fuel-burning space conditioning appliances, design options for direct heaters have the effect of impacting the sales of electric space heating equipment. In the trial standard level cases where SO₂ and NO_x emissions have increased, design options for direct heating equipment have actually increased the sales of electric space heating equipment. This ultimately results in increased electricity use and, therefore, increases in the amount of power plant emissions.

3.3.2 Carbon Dioxide Emissions

The cumulative increase in CO₂ emissions from level 5 design changes is 60 million tons of CO₂. For the year 1996, the estimated CO₂ increase is 173 thousand tons of CO₂ or about 0.01% of estimated U.S. power plant CO₂ emissions in 1996. For the year 2030, the estimated CO₂ increase is 285 thousand tons of CO₂ or about 0.01% of estimated U.S. power plant CO₂ emissions in 2030.

The reasons that were given for increased SO₂ and NO_x emissions (namely, increased sales of electric space heating equipment) also serve to explain why CO₂ emissions have increased in some trial standard level cases.

Table 21
Reduction of Pollutants for Direct Heating Equipment - 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	84	84	0.00%
2000	84	55	139	0.01%
2005	84	0	84	0.00%
2010	0	0	0	0.00%
2015	85	0	85	0.00%
2020	0	0	0	0.00%
2025	0	84	84	0.00%
2030	83	-55	28	0.00%

Cumulative CO2 reduction, 1996-2030 = 2 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	157	157	0.00%
2000	301	0	301	0.00%
2005	257	0	257	0.00%
2010	0	0	0	0.00%
2015	178	0	178	0.00%
2020	0	0	0	0.00%
2025	0	157	157	0.00%
2030	83	0	83	0.00%

Cumulative SO2 reduction, 1996-2030 = 5,474 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	65	65	0.00%
2000	224	53	277	0.00%
2005	207	0	207	0.00%
2010	0	0	0	0.00%
2015	165	0	165	0.00%
2020	0	0	0	0.00%
2025	0	65	65	0.00%
2030	102	-53	49	0.00%

Cumulative NOx reduction, 1996-2030 = 4,477 tons

Table 22
Reduction of Pollutants for Direct Heating Equipment - 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	194	280	0.01%
2000	84	220	304	0.01%
2005	169	220	389	0.01%
2010	170	220	390	0.01%
2015	338	194	533	0.01%
2020	337	55	392	0.01%
2025	334	84	418	0.01%
2030	331	-55	276	0.01%

Cumulative CO2 reduction, 1996-2030 = 14 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	157	640	0.00%
2000	301	0	301	0.00%
2005	514	0	514	0.01%
2010	444	0	444	0.01%
2015	712	157	868	0.01%
2020	570	0	570	0.01%
2025	438	157	594	0.01%
2030	331	0	331	0.01%

Cumulative SO2 reduction, 1996-2030 = 19,780 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	170	473	0.01%
2000	224	210	434	0.01%
2005	413	210	623	0.01%
2010	385	210	595	0.01%
2015	660	170	830	0.01%
2020	570	53	623	0.01%
2025	480	65	545	0.01%
2030	407	-53	354	0.01%

Cumulative NOx reduction, 1996-2030 = 21,442 tons

Table 23
Reduction of Pollutants for Direct Heating Equipment - 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	86	165	251	0.01%
2000	84	385	469	0.02%
2005	253	495	748	0.03%
2010	340	440	780	0.02%
2015	508	359	867	0.02%
2020	675	249	924	0.02%
2025	668	224	891	0.02%
2030	662	84	747	0.02%

Cumulative CO2 reduction, 1996-2030 = 26 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	301	0	301	0.00%
2005	770	0	770	0.01%
2010	887	0	887	0.01%
2015	1,067	157	1,224	0.02%
2020	1,140	157	1,297	0.02%
2025	876	313	1,189	0.02%
2030	662	157	818	0.02%

Cumulative SO2 reduction, 1996-2030 = 31,644 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	158	461	0.01%
2000	224	368	592	0.01%
2005	620	473	1,092	0.02%
2010	771	420	1,191	0.02%
2015	990	327	1,317	0.02%
2020	1,140	222	1,363	0.02%
2025	960	183	1,142	0.02%
2030	813	65	878	0.01%

Cumulative NOx reduction, 1996-2030 = 37,241 tons

Table 24
Reduction of Pollutants for Direct Heating Equipment - 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	-172	385	213	0.01%
2000	-671	766	96	0.00%
2005	-1,183	1,012	-171	-0.01%
2010	-1,275	928	-347	-0.01%
2015	-846	821	-25	0.00%
2020	-422	686	264	0.01%
2025	-167	550	383	0.01%
2030	0	301	301	0.01%

Cumulative CO2 reduction, 1996-2030 = 2 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	-2,409	-313	-2,722	-0.03%
2005	-3,595	-469	-4,064	-0.05%
2010	-3,327	-626	-3,953	-0.05%
2015	-1,779	-313	-2,092	-0.03%
2020	-713	-157	-869	-0.01%
2025	-219	0	-219	0.00%
2030	0	-157	-157	0.00%

Cumulative SO2 reduction, 1996-2030 = -72,413 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	368	-239	0.00%
2000	-1,793	763	-1,031	-0.02%
2005	-2,892	1,013	-1,880	-0.03%
2010	-2,891	948	-1,944	-0.03%
2015	-1,649	815	-834	-0.01%
2020	-713	670	-43	0.00%
2025	-240	525	285	0.00%
2030	0	303	303	0.01%

Cumulative NOx reduction, 1996-2030 = -26,942 tons

Table 25
Reduction of Pollutants for Direct Heating Equipment - 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	-775	601	-173	-0.01%
2000	-2,599	1,390	-1,209	-0.05%
2005	-4,478	1,933	-2,545	-0.09%
2010	-5,100	2,013	-3,086	-0.10%
2015	-4,147	1,687	-2,460	-0.07%
2020	-3,036	1,445	-1,591	-0.04%
2025	-2,087	1,258	-829	-0.02%
2030	-1,242	957	-285	-0.01%

Cumulative CO2 reduction, 1996-2030 = -60 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	-4,349	-313	-4,662	-0.04%
2000	-9,334	-1,096	-10,429	-0.12%
2005	-13,609	-1,722	-15,330	-0.18%
2010	-13,307	-1,878	-15,185	-0.18%
2015	-8,716	-1,565	-10,281	-0.14%
2020	-5,131	-1,096	-6,226	-0.09%
2025	-2,737	-626	-3,363	-0.06%
2030	-1,241	-470	-1,710	-0.04%

Cumulative SO2 reduction, 1996-2030 = -319,957 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	-2,730	605	-2,125	-0.03%
2000	-6,949	1,435	-5,514	-0.08%
2005	-10,949	2,015	-8,934	-0.13%
2010	-11,564	2,108	-9,457	-0.13%
2015	-8,081	1,765	-6,316	-0.09%
2020	-5,131	1,488	-3,643	-0.05%
2025	-2,999	1,263	-1,736	-0.03%
2030	-1,525	960	-565	-0.01%

Cumulative NOx reduction, 1996-2030 = -183,878 tons

3.4 MOBILE HOME FURNACES

Changes in the amount of CO₂, SO₂, and NO_x emitted at trial standards levels 1 through 6 are summarized in Tables 26 through 31.

3.4.1 Sulfur and Nitrogen Oxide Emissions

Sulfur dioxide emissions would be increased by a cumulative total of up to 0.27 million tons between 1996 and 2030 in the level 6 scenario. In the year 1996, increases in sulfur dioxide will represent about 0.01% of the SO₂ emissions estimated to come from power plants in that year. In the year 2030, increases in SO₂ emissions will represent about 0.18% of the SO₂ emissions estimated to come from power plants in that year. Although increased in the level 6 scenario, SO₂ emissions would be decreased between 1996 and 2030 in the level 1 scenario. However, as discussed earlier, 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 6 design changes to mobile home furnaces would result in an estimated increase in NO_x emissions of 0.087 million tons between 1996 and 2030. NO_x increases would represent 0.005% and 0.04% of the NO_x emissions estimated to come from power plants in the years 1996 and 2030, respectively.

It should be noted that, although mobile home furnaces consist entirely of fuel-burning space conditioning appliances, design options for mobile home furnaces have the effect of impacting the sales of electric space heating equipment. In the trial standard level cases where SO₂ and NO_x emissions have increased, design options for mobile home furnaces have actually increased the sales of electric space heating equipment. This ultimately results in increased electricity use and, therefore, increases in the amount of power plant emissions.

3.4.2 Carbon Dioxide Emissions

The cumulative increase in CO₂ emissions from level 6 design changes is 49 million tons of CO₂. For the year 1996, the estimated CO₂ reduction is 5 thousand tons of CO₂ or about 0.001% of estimated U.S. power plant CO₂ emissions in 1996. For the year 2030, the estimated CO₂ increase is 2464 thousand tons of CO₂ or about 0.05% of estimated U.S. power plant CO₂ emissions in 2030.

The reasons that were given for increased SO₂ and NO_x emissions (namely, increased sales of electric space heating equipment) also serve to explain why CO₂ emissions have increased in some trial standard level cases.

Table 26
Reduction of Pollutants for Mobile Home Furnaces - 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	0	0	0.00%
2000	8	11	19	0.00%
2005	8	25	33	0.00%
2010	8	30	39	0.00%
2015	8	39	47	0.00%
2020	0	44	44	0.00%
2025	0	30	30	0.00%
2030	0	25	25	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	30	0	30	0.00%
2005	26	16	41	0.00%
2010	22	16	38	0.00%
2015	18	31	49	0.00%
2020	0	31	31	0.00%
2025	0	16	16	0.00%
2030	0	16	16	0.00%

Cumulative SO2 reduction, 1996-2030 = 992 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	0	0	0.00%
2000	22	11	33	0.00%
2005	21	22	43	0.00%
2010	19	28	47	0.00%
2015	16	34	50	0.00%
2020	0	39	39	0.00%
2025	0	28	28	0.00%
2030	0	22	22	0.00%

Cumulative NOx reduction, 1996-2030 = 1,151 tons

Table 27
Reduction of Pollutants for Mobile Home Furnaces - 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	0	11	11	0.00%
2000	-8	47	38	0.00%
2005	-17	68	51	0.00%
2010	-34	87	53	0.00%
2015	-42	101	59	0.00%
2020	-51	98	47	0.00%
2025	-50	78	28	0.00%
2030	-58	67	10	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	-30	-16	-46	0.00%
2005	-51	-47	-98	0.00%
2010	-89	-63	-151	0.00%
2015	-89	-78	-167	0.00%
2020	-86	-94	-179	0.00%
2025	-66	-110	-175	0.00%
2030	-58	-110	-167	0.00%

Cumulative SO2 reduction, 1996-2030 = -4,696 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	10	10	0.00%
2000	-22	46	24	0.00%
2005	-41	70	28	0.00%
2010	-77	90	12	0.00%
2015	-82	104	22	0.00%
2020	-86	103	17	0.00%
2025	-72	86	14	0.00%
2030	-71	75	4	0.00%

Cumulative NOx reduction, 1996-2030 = 541 tons

Table 28
Reduction of Pollutants for Mobile Home Furnaces - 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	-17	30	12	0.00%
2000	-59	92	33	0.00%
2005	-127	137	10	0.00%
2010	-204	174	-30	0.00%
2015	-254	183	-70	0.00%
2020	-278	169	-109	0.00%
2025	-267	125	-142	0.00%
2030	-240	90	-150	0.00%

Cumulative CO2 reduction, 1996-2030 = -2 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	-97	-47	-144	0.00%
2000	-211	-157	-367	0.00%
2005	-385	-297	-682	-0.01%
2010	-532	-423	-955	-0.01%
2015	-534	-548	-1,081	-0.01%
2020	-470	-626	-1,096	-0.02%
2025	-350	-626	-976	-0.02%
2030	-240	-579	-819	-0.02%

Cumulative SO2 reduction, 1996-2030 = -28,747 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	-61	33	-28	0.00%
2000	-157	103	-54	0.00%
2005	-310	160	-150	0.00%
2010	-463	208	-255	0.00%
2015	-495	229	-266	0.00%
2020	-470	223	-247	0.00%
2025	-384	181	-203	0.00%
2030	-295	143	-152	0.00%

Cumulative NOx reduction, 1996-2030 = -6,507 tons

Table 29
Reduction of Pollutants for Mobile Home Furnaces - 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	-34	37	3	0.00%
2000	-117	95	-22	0.00%
2005	-245	153	-92	0.00%
2010	-365	172	-194	-0.01%
2015	-465	172	-294	-0.01%
2020	-506	140	-366	-0.01%
2025	-476	82	-393	-0.01%
2030	-414	37	-377	-0.01%

Cumulative CO2 reduction, 1996-2030 = -8 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	-193	-94	-287	0.00%
2000	-422	-313	-735	-0.01%
2005	-745	-563	-1,308	-0.02%
2010	-954	-845	-1,799	-0.02%
2015	-978	-1,080	-2,058	-0.03%
2020	-855	-1,221	-2,076	-0.03%
2025	-624	-1,205	-1,829	-0.03%
2030	-414	-1,096	-1,509	-0.03%

Cumulative SO2 reduction, 1996-2030 = -54,358 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	-121	45	-76	0.00%
2000	-314	122	-192	0.00%
2005	-599	202	-397	-0.01%
2010	-829	248	-581	-0.01%
2015	-907	271	-636	-0.01%
2020	-855	254	-601	-0.01%
2025	-684	198	-486	-0.01%
2030	-508	144	-365	-0.01%

Cumulative NOx reduction, 1996-2030 = -15,781 tons

Table 30
Reduction of Pollutants for Mobile Home Furnaces - 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	-77	111	34	0.00%
2000	-268	293	25	0.00%
2005	-558	449	-109	0.00%
2010	-841	527	-314	-0.01%
2015	-1,075	537	-537	-0.01%
2020	-1,164	420	-744	-0.02%
2025	-1,119	264	-854	-0.02%
2030	-1,035	147	-888	-0.02%

Cumulative CO2 reduction, 1996-2030 = -15 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	-435	-141	-576	0.00%
2000	-964	-579	-1,543	-0.02%
2005	-1,695	-1,158	-2,853	-0.03%
2010	-2,196	-1,737	-3,933	-0.05%
2015	-2,259	-2,301	-4,560	-0.06%
2020	-1,967	-2,723	-4,690	-0.07%
2025	-1,467	-2,848	-4,315	-0.07%
2030	-1,034	-2,801	-3,835	-0.08%

Cumulative SO2 reduction, 1996-2030 = -122,401 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	-273	120	-153	0.00%
2000	-717	337	-380	-0.01%
2005	-1,364	543	-821	-0.01%
2010	-1,908	675	-1,233	-0.02%
2015	-2,095	740	-1,354	-0.02%
2020	-1,967	670	-1,297	-0.02%
2025	-1,607	534	-1,074	-0.02%
2030	-1,271	417	-854	-0.01%

Cumulative NOx reduction, 1996-2030 = -33,753 tons

Table 31
Reduction of Pollutants for Mobile Home Furnaces - 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	-164	159	-5	0.00%
2000	-595	372	-223	-0.01%
2005	-1,217	544	-673	-0.02%
2010	-1,827	637	-1,190	-0.04%
2015	-2,310	607	-1,703	-0.05%
2020	-2,462	335	-2,127	-0.05%
2025	-2,379	45	-2,334	-0.05%
2030	-2,268	-196	-2,464	-0.05%

Cumulative CO2 reduction, 1996-2030 = -49 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	-918	-297	-1,216	-0.01%
2000	-2,138	-1,330	-3,468	-0.04%
2005	-3,697	-2,676	-6,374	-0.07%
2010	-4,768	-3,881	-8,649	-0.10%
2015	-4,856	-5,071	-9,927	-0.13%
2020	-4,162	-6,025	-10,187	-0.15%
2025	-3,120	-6,370	-9,490	-0.16%
2030	-2,266	-6,479	-8,745	-0.18%

Cumulative SO2 reduction, 1996-2030 = -269,787 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	-576	181	-395	0.00%
2000	-1,591	487	-1,104	-0.02%
2005	-2,975	784	-2,191	-0.03%
2010	-4,144	992	-3,152	-0.04%
2015	-4,502	1,081	-3,422	-0.05%
2020	-4,162	915	-3,246	-0.05%
2025	-3,419	673	-2,746	-0.04%
2030	-2,786	454	-2,332	-0.04%

Cumulative NOx reduction, 1996-2030 = -87,340 tons

3.5 RANGES AND OVENS

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 32 through 36, trial standards levels 1 through 5 for conventional ovens are summarized in Tables 37 through 41, and trial standards levels 1 through 5 for microwave ovens are summarized in Tables 42 through 46.

3.5.1 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 sulfur dioxide 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. As discussed earlier, 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 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 sulfur dioxide 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 sulfur dioxide 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.

3.5.2 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. power plant 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. power plant 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. power plant 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. power plant 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. power plant 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. power plant CO₂ emissions in 2030.

Table 32
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 33
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 34
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 35
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 36
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 37
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 38
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 39
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 40
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 41
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 42
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 43
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 44
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 45
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 46
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

3.6 POOL HEATERS

Decreases in the amounts of CO₂, SO₂, and NO_x emitted at trial standards levels 1 through 4 for gas pool heaters are summarized in Tables 47 through 50.

3.6.1 Sulfur and Nitrogen Oxide Emissions

Sulfur dioxide emissions would be decreased by a cumulative total of up to 0.00 million tons between 1996 and 2030 in the level 4 scenario. In the year 1996, decreases in sulfur dioxide will represent about 0.00% of the SO₂ emissions estimated to come from power plants in that year. In the year 2030, decreases in SO₂ emissions will represent about 0.00% of the SO₂ emissions estimated to come from power plants in that year.

Level 4 design changes to pool heaters would result in an estimated decrease in NO_x emissions of 0.04 million tons between 1996 and 2030. NO_x decreases would represent 0.003% and 0.03% of the NO_x emissions estimated to come from power plants in the years 1996 and 2030, respectively.

3.6.2 Carbon Dioxide Emissions

The cumulative reduction in CO₂ emissions from level 4 design changes is 43 million tons of CO₂. For the year 1996, the estimated CO₂ reduction is 270 thousand tons of CO₂ or about 0.01% of estimated U.S. power plant CO₂ emissions in 1996. For the year 2030, the estimated CO₂ reduction is 1744 thousand tons of CO₂ or about 0.04% of estimated U.S. power plant CO₂ emissions in 2030.

Table 47
Reduction of Pollutants for Pool Heaters - 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	110	110	0.00%
2000	0	292	292	0.01%
2005	0	292	292	0.01%
2010	0	198	198	0.01%
2015	0	44	44	0.00%
2020	0	-11	-11	0.00%
2025	0	-11	-11	0.00%
2030	0	-17	-17	0.00%

Cumulative CO2 reduction, 1996-2030 = 4 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 = 0 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	105	105	0.00%
2000	0	278	278	0.00%
2005	0	278	278	0.00%
2010	0	189	189	0.00%
2015	0	42	42	0.00%
2020	0	-10	-10	0.00%
2025	0	-11	-11	0.00%
2030	0	-16	-16	0.00%

Cumulative NOx reduction, 1996-2030 = 3,864 tons

Table 48
Reduction of Pollutants for Pool Heaters - 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	0	149	149	0.01%
2000	0	396	396	0.02%
2005	0	479	479	0.02%
2010	0	440	440	0.01%
2015	0	319	319	0.01%
2020	0	292	292	0.01%
2025	0	319	319	0.01%
2030	0	347	347	0.01%

Cumulative CO2 reduction, 1996-2030 = 12 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 = 0 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	142	142	0.00%
2000	0	378	378	0.01%
2005	0	457	457	0.01%
2010	0	420	420	0.01%
2015	0	305	305	0.00%
2020	0	278	278	0.00%
2025	0	305	305	0.00%
2030	0	331	331	0.01%

Cumulative NOx reduction, 1996-2030 = 11,870 tons

Table 49
Reduction of Pollutants for Pool Heaters - 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	226	226	0.01%
2000	0	616	616	0.02%
2005	0	891	891	0.03%
2010	0	990	990	0.03%
2015	0	963	963	0.03%
2020	0	1,018	1,018	0.03%
2025	0	1,122	1,122	0.03%
2030	0	1,232	1,232	0.03%

Cumulative CO2 reduction, 1996-2030 = 32 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 = 0 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	215	215	0.00%
2000	0	588	588	0.01%
2005	0	851	851	0.01%
2010	0	945	945	0.01%
2015	0	919	919	0.01%
2020	0	971	971	0.01%
2025	0	1,071	1,071	0.02%
2030	0	1,176	1,176	0.02%

Cumulative NOx reduction, 1996-2030 = 30,508 tons

Table 50
Reduction of Pollutants for Pool Heaters - 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	0	270	270	0.01%
2000	0	748	748	0.03%
2005	0	1,128	1,128	0.04%
2010	0	1,304	1,304	0.04%
2015	0	1,326	1,326	0.04%
2020	0	1,430	1,430	0.04%
2025	0	1,584	1,584	0.04%
2030	0	1,744	1,744	0.04%

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	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 = 0 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	257	257	0.00%
2000	0	714	714	0.01%
2005	0	1,076	1,076	0.02%
2010	0	1,244	1,244	0.02%
2015	0	1,265	1,265	0.02%
2020	0	1,365	1,365	0.02%
2025	0	1,512	1,512	0.02%
2030	0	1,664	1,664	0.03%

Cumulative NOx reduction, 1996-2030 = 41,176 tons

3.7 FLUORESCENT BALLASTS

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 51 through 53 while trial standards levels 1 through 3 for the sensitivity (high efficiency base) case are summarized in Tables 54 through 56. For an explanation of the differences in the two cases, please refer to Volume B, Chapter 2 of this Technical Support Document.

3.7.1 Sulfur and Nitrogen Oxide Emissions

Reference Case

Sulfur dioxide 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 sulfur dioxide 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. As discussed earlier, 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 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

Sulfur dioxide 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 sulfur dioxide 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.

3.7.2 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. power plant 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. power plant 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. power plant 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. power plant CO₂ emissions in 2030.

Table 51
Reduction of Pollutants for Fluorescent Ballasts (Low DSM 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 52
Reduction of Pollutants for Fluorescent Ballasts (Low DSM 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 53
Reduction of Pollutants for Fluorescent Ballasts (Low DSM 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 54
Reduction of Pollutants for Fluorescent Ballasts (High DSM 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 55
Reduction of Pollutants for Fluorescent Ballasts (High DSM 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 56
Reduction of Pollutants for Fluorescent Ballasts (High DSM 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

3.8 TELEVISIONS

Decreases in the amounts of CO₂, SO₂, and NO_x emitted at trial standards levels 1 through 3 are summarized in Tables 57 through 59.

3.8.1 Sulfur and Nitrogen Oxide Emissions

Sulfur dioxide 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 sulfur dioxide 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. As discussed earlier, 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 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.

3.8.2 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. power plant 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. power plant CO₂ emissions in 2030.

Table 57
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 58
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 59
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

4 REFERENCES

1. National Appliance Energy Conservation Act, (NAECA). 1987. Public Law 100-12.
2. 1991. *Improving Technology: Modeling Energy Futures for National Energy Strategy*. Service Report to the 1991 National Energy Strategy, SR/NES/90-01.
3. J. Koomey. 1990. *Comparative Analysis of Monetary Estimates of External Environmental Costs Associated with Combustion of Fossil Fuels*. Lawrence Berkeley Laboratory Report, LBL-28313, Berkeley CA, July, 1990.
4. *Ibid.*

REGULATORY IMPACT ANALYSIS

Energy Conservation Standards for Consumer Products

Covering: Water Heaters, Mobile Home Furnaces, Direct Heating Equipment, Televisions, Kitchen Ranges and Ovens, Room Air Conditioners, Pool Heaters, and Fluorescent Light Ballasts

U.S. DEPARTMENT OF ENERGY
Conservation and Renewable Energy Office of Building Technologies

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REGULATORY IMPACT ANALYSIS

1. INTRODUCTION

Part B of Title III of the Energy Policy and Conservation Act (EPCA) (P.L. 94-163), as amended by the National Energy Conservation Policy Act (NECPA) (P.L. 95-619), by the National Appliance Energy Conservation Act (NAECA) (P.L. 100-12), and by the National Energy Conservation Amendments of 1988 (NECA) (P.L. 100-357), created the Energy Conservation Program for Consumer Products other than automobiles. The consumer products covered by this program (often referred to hereafter as "covered products") are: refrigerators, refrigerator-freezers and freezers; dishwashers; clothes dryers; water heaters; central air conditioners and central air conditioning heat pumps; furnaces; direct heating equipment; television sets; kitchen ranges and ovens; clothes washers; room air conditioners; pool heaters; fluorescent light ballasts; and any other consumer product classified by the Secretary of Energy [Section 322]. To date, the Secretary has not classified any additional products.

For 12 covered products, the Act prescribes an initial federal energy conservation standard [Section 325 (b) - (h)]. The Act establishes effective dates for the standards in 1988, 1990, 1992, or 1993, depending on the product, and specifies that the standards are to be reviewed by the Department within three to ten years, also depending on the product [Section 325(b) - (h)]. After the specified three- to ten-year period, DOE may promulgate new standards for each product; however, the Secretary may not prescribe any amended standard that increases the maximum allowable energy use, or decreases the minimum required energy efficiency, of a covered product [Section 325 (1) (1)].

The Act requires DOE to publish a final rule no later than January 1, 1992, to determine if the standards on water heaters, pool heaters, room air conditioners, mobile home furnaces, direct heating equipment, ranges/ovens, and fluorescent lamp ballasts should be amended. The Act does not specify a date for televisions [Section 325(g) (4) (A) (i)]. These eight types of products are the subject of the rulemaking for which this Regulatory Impact Analysis is being issued.

Any new or amended standard must be designed to achieve the maximum improvement in energy efficiency that is technologically feasible and economically justified [Section 325 (1) (2) (A)].

Section 325 (1) (2) (B) (i) provides that before DOE determines whether a standard is economically justified, it must first solicit comments on a proposed standard. After reviewing comments on the proposal, DOE must then determine that the benefits of the standard exceed its burdens, based, to the greatest extent practicable, on a weighing of the following seven factors:

- (1) The economic impact of the standard on the manufacturers and on the consumers of the products subject to such standard;
- (2) The savings in operating costs throughout the estimated average life of the covered product in the type (or class) compared to any increase in the price of, or in the initial charges for, or maintenance expenses of, the covered products which are likely to result from the imposition of the standard;
- (3) The total projected amount of energy savings likely to result directly from the imposition of the standard;
- (4) Any lessening of the utility or the performance of the covered products likely to result from the imposition of the standard;
- (5) The impact of any lessening of competition, determined in writing by the Attorney General, that is likely to result from the imposition of the standard;
- (6) The need for national energy conservation; and
- (7) Other factors the Secretary considers relevant.

In addition, the Act specifies criteria for petitions to DOE in regard to amendments to standards [Section 325 (k)]. Under the Act, any person may petition the Department to conduct a rulemaking to amend a federal energy conservation standard for any covered product [Section 325 (k) (1)]. The Department must grant such a petition if it determines that an amended standard will result in significant conservation of energy, is technologically feasible, and is cost-effective [Section 325 (k) (2)].

This Regulatory Analysis describes the analyses performed by DOE to arrive at the proposed energy efficiency standards for the product types listed above.

Executive Order 12291 (46 FR 13193, February 19, 1981) directs that, in proposing a major rule, an agency perform a regulatory analysis. Such an analysis presents major alternatives to the regulation that could achieve substantially the same regulatory goal at lower cost, as well as a description of the costs and benefits (including potential net benefits) of the proposed rule.

DOE has determined that this proposed rule is a "major rule."

Since Congress mandated that DOE promulgate performance standards, the only other alternative within the boundaries of the law is a no standard alternative. However, in preparing this Regulatory Analysis, the list of alternatives has been expanded to include alternatives that would require new enabling legislation or statutory amendments.

This Regulatory Analysis is concerned with the projected economic impacts of the standards, and their major alternatives, on the nation as a whole.

In addition to examining possible alternatives to the proposed standards, this Regulatory Analysis examines the way in which performance criteria and other factors are defined and measured for the proposed standards. The proposed alternatives are examined for reasonableness and possible biases that might affect the success of the standards in achieving the legislated goals of energy conservation and reduced demand for energy. The analysis briefly presents the results of the Technical Support Document (TSD) (1), and explains how these results were used to determine the relative impact of the proposed standards on the nation.

2. DESCRIPTION AND ANALYSIS OF MAJOR ALTERNATIVES

There are many methods to achieve energy conservation through the increased energy efficiency of consumer products. This section describes and analyzes various regulatory and non-regulatory alternatives and their effectiveness in conserving energy.

The alternatives examined in this analysis ranged from the no-action alternative or the "base case" against which the benefits of other alternatives are measured to alternatives requiring new legislation for implementation.

Each alternative has been analyzed in comparison to the other alternatives in terms of potential energy savings, net present value, and other impacts that differ among the alternatives. A summary of this comparative analysis is presented in the following section. A detailed discussion and quantitative description of each alternative is presented in the remaining sections of this chapter.

2.1 Comparative Analysis of the Alternatives

To compare each alternative quantitatively to the proposed conservation standards in terms of energy savings and the net present value (or cost savings), it is necessary to quantify the effect of each alternative on the purchase and use of energy-efficient consumer products. Each alternative to the proposed regulation was quantified so that inputs to the forecasting model (LBL-REM or EPRI COMMEND) could be determined. The forecasting model was used to calculate the energy use and the net present value corresponding to each alternative. The key inputs to the forecasting model are:

- energy prices and escalation factors,
- implicit market discount rates for trading off purchase price against operating expense when choosing appliance efficiency,
- consumer demand and income elasticities,
- price versus efficiency relationships for each consumer product, and

- appliance stock data (purchase of new appliances or turnover rates for inventories).

An example of the input to the forecasting model is shown in Table 1. Only those parameters that were needed to specify the alternatives were changed from the base case. Otherwise, all aspects of the base case remained constant throughout the analysis to permit a quantitative comparison of the alternatives without extraneous effects.

The results of the simulations are summarized in the first three columns of Table 2.2 for each alternative evaluated. All results are relative to the base or no-action case so that the energy savings resulting from each alternative can be assessed readily. Most alternatives would result in some energy savings and in positive net present value compared to the base case. As the comparison shows, the proposed approach results in appreciably higher energy savings and a greater national net present value than any of the other alternatives.

Table 1 Summary of Key Inputs To Simulate the Base Case. (A) Escalation Rates For Energy Prices and Household Income

	Electricity		Natural Gas	Distil. Oil	Household Income
	Comm.	Resid.			
1991-1995	1.1%	0.6%	1.3%	-0.9%	0.1%
1996-2000	-0.9%	-0.5%	1.5%	0.9%	0.7%
2001-2005	0.4%	0.8%	4.1%	2.5%	0.7%
2006-2010	0.3%	0.6%	2.2%	1.3%	1.3%
2011-2030	0.3%	0.6%	2.2%	1.3%	1.1%

Table 2 Market Discount Rates for Efficiency Choice (Percent)

Television Sets	51
Water Heaters	
Electric Storage Water Heaters	191
Gas-fired Storage Water Heaters	37
Instantaneous Gas-fired Water Heaters	14
Oil-fired Storage Water Heaters	124
Gas-fired Spa & Pool Heaters	34
Direct Heat Equipment	
Fan wall heater up to 42 kBtu	7
Fan wall heater over 42 kBtu	7
Floor furnace up to 37 kBtu	26
Floor furnace over 37 kBtu	53
Gravity wall heater up to 10 kBtu	7
Gravity wall heater 10 to 12 kBtu	14
Gravity wall heater 12 to 15 kBtu	21
Gravity wall heater 15 to 19 kBtu	21
Gravity wall heater 19 to 27 kBtu	24
Gravity wall heater 27 to 46 kBtu	41
Gravity wall heater over 46 kBtu	47
Room heater up to 18 kBtu	31
Room heater 18 to 20 kBtu	40
Room heater 20 to 27 kBtu	21
Room heater 27 to 46 kBtu	26
Room heater over 46 kBtu	17
Mobile Home Furnaces	
Gas-fired mobile home furnaces	31
Oil-fired mobile home furnaces	21
Room Air Conditioners	
Room A/C up to 6 kBtu with louvers	76
Room A/C up to 6 kBtu w/o louvers	76
Room A/C 6 to 8 kBtu with louvers	35
Room A/C 6 to 8 kBtu w/o louvers	35
Room A/C 8 to 14 kBtu with louvers	34
Room A/C 8 to 14 kBtu w/o louvers	34
Room A/C 14 to 20 kBtu with louvers	54
Room A/C 14 to 20 kBtu w/o louvers	54
Room A/C over 20 kBtu with louvers	38
Room A/C over 20 kBtu w/o louvers	38
Heat pump room A/C, reversing valve with louvers	41
Heat pump room A/C, reversing valve w/o louvers	41

**Table 2 Market Discount Rates for Efficiency
Choice (Percent) Cont'd**

Kitchen Ranges and Ovens

Electric cooktop, coil element	20
Electric cooktop, smooth element	20
Gas cooktop	59
Electric oven, non-self-cleaning	61
Electric oven, self-cleaning	14
Gas oven, non-self-cleaning	49
Gas oven, self-cleaning	32
Microwave oven	50

Table 3 Market Share Elasticities

	TV	Elec Water Heater	Gas Water Heater	Oil Water Heater	Pool Heater	Direct Heating	Gas MobHm Furnace	Oil MobHm Furnace	Room A/C
Operating Expense	-0.15	-0.50	-0.35	-0.50	-0.10	-0.65	-0.65	-0.60	-0.20
Income	0.00	0.00	0.18	0.00	0.10	0.25	0.25	-0.20	0.60
Equipment price (existing house)	-0.95	-0.07	-0.10	-0.19	-0.57	-0.37	-0.44	-0.31	-0.22
Equipment price (new house)	-0.82	-0.06	-0.09	-0.18	-0.64	-0.42	-0.51	-0.37	-0.17
	Electric Cooktop	Gas Cooktop	Elec Oven	Gas Oven	Micro- wave Oven				
Operating Expense	-0.15	-0.14	-0.15	-0.14	-0.15				
Income	0.00	0.12	0.00	0.12	0.00				
Equipment price (existing house)	-0.42	-0.18	-0.34	-0.79	-0.26				
Equipment price (new house)	-0.31	-0.13	-0.25	-0.58	-0.21				

Table 4 Consumer Price vs Energy Consumption (Example: Room A/C < 6K Btuh, with side louvers)

	Design Option	Purchase Price (\$1990)	kWh/Year
0	Baseline	287.91	532.1
1	0 + Evap/Cond Enhanced Fins	288.89	501.5
2	1 + PSC Fan Motor	292.68	470.3
3	2 + /Evap/Cond Grooved Tubes	296.23	445.7
4	3 + Add Subcooler	301.55	421.8
5	4 + Increase Comp EER to 11.0	303.34	414.6
6	5 + Increase Evap.Cond Coil Area	330.33	398.5
7	6 + Variable Speed Compressor	419.65	358.6
8	7 + Brushless D.C. Fan Motor	497.07	352.3
9	5 + Increase Comp EER to 11.5	320.46	397.3
10	9 + Increase Evap/Cond Coil Area	342.52	382.3
11	10 + Variable Speed Compressor	430.15	334.0
12	11 + Brushless D.C. Fan Motor	507.95	337.7

The impacts of measures of each alternative program are:

- Residential Energy Use (quadrillion Btu): Cumulative, 1996-2030 for each of the eight products. Electricity consumption is reported as primary energy (11,500 Btu = 1 kWh).
- Energy Savings. Cumulative energy use from base case projection less alternative-policy-case projection.
- Net Present Value. Value of future savings from appliances bought in the period 1996-2030. Calculated as difference: present value of equipment and energy expenditures in base case less present value of expenditures in alternative policy case. Future fuel and equipment expenditures are discounted to 1990 using 4% real discount rate. Fuel expenses are calculated for the life of the appliance.

The additional columns presented in Table 5 focus on other aspects of each alternative that are pertinent to the regulatory analysis, including:

- equity impacts (or effects on the well-being of the nation),
- legislative authority for implementing the alternative,
- major barriers to implementation and enforcement (other than legislative),
- impact of the alternative on competition, and
- compliance and reporting requirements of each alternative.

These factors for each alternative program are compared to the proposed standards. None of the alternatives show energy or economic savings comparable to the proposed standards. However, the proposed approach appears to be less favorable than some of the other program alternatives in competition and reporting/compliance requirements. (see Table 5.) Those program alternatives (voluntary targets, enhanced labeling/consumer education) that involve non-mandatory methods for achieving more energy-efficient consumer products fare better in these two areas. However, the reporting/compliance requirements and the potential effects on competition of the performance standards must be weighed against the greater and more certain energy savings of the proposed approach compared to what the alternatives could achieve in this area.

2.2 No-Action Alternative

This alternative was analyzed as the "base case" and assumes that the proposed standards are not implemented. The no-action alternative does not imply that no energy savings would be realized; some energy savings will be achieved because of higher energy costs, the continuation of other federal energy conservation activities, and a variety of state and utility company programs aimed at increased appliance efficiency. These programs include the deregulation of energy prices, consumer product labeling, the public education and information program, and the residual effects of state and federal consumer product efficiency standards already in place.

2.2.1 Energy Prices

In recent years, the prices of natural gas and oil have been deregulated. Projected energy prices to the year 2010 for the residential sector were developed by DOE in the Annual Report to Congress (1991). The prices after the year 2010 were extrapolated:

- In real terms, commercial electricity prices are projected to increase at 1.1% per year until 1995, then decline at 0.9% per year until 2000, and then increase at 0.4% per year until 2005. After 2005, commercial electricity prices are projected to rise at 0.3% per year.

- Residential electricity prices are projected to increase at 0.6% per year until 1995, then decline at 0.5% per year until 2000, and then increase at 0.8% per year until 2005. After 2005, residential electricity prices are projected to rise at 0.6% per year.
- Residential natural gas prices are projected to rise at 1.3% per year until 1995, then at 1.5% per year until 2000, and then at 4.1% per year until 2005. After 2005, natural gas prices are projected to rise at 2.2% per year.
- Distillate prices are projected to decline at 0.9% per year until 1995, then increase at 0.9% per year until 2000, and then rise at 2.5% per year until 2005. After 2005, distillate prices are projected to rise at 1.3% per year.

2.2.2 Increasing Consumer Information

Congress has mandated in the Energy Policy and Conservation Act (EPCA) (P.L. 94-163) both a labeling program and a complementary consumer education and information program. The labeling program took effect on May 21, 1980, implemented by the Federal Trade Commission (FTC); the public education and information program is being handled by DOE.

Under the labeling program, consumer awareness of the relative efficiencies of consumer products available in the marketplace is expected to increase. That is, the basic information that consumers need to make a *rational* purchase decision would be more readily available to them.

The consumer education and information program involves the development and expansion of existing federal energy information programs and is designed to educate consumers about the value and use of energy labels on products. The educational activities focus on steering the consumer away from the idea of minimizing first cost and on promoting the use of life-cycle costing as the primary factor in selecting a consumer product for purchase.

There are several drawbacks to relying wholly on the education program, even in conjunction with the labeling program, to achieve the desired results:

- Consumer education and labeling programs are directed only at the demand for consumer products; they will not guarantee the appropriate supply-side responses by manufacturers;
- In many cases, as in new residential construction, consumer products are installed by builders, and minimum first cost is an overriding consideration;
- Energy efficiency is only one factor in consumers' purchase decisions; and
- There is a long lag before the effect of such educational activities is manifest in the marketplace.

Table 2.2 Expected Impacts of Program Alternatives

Alternative Impacts	Regulated Products		Net Present Value for Fuel and Equipment (in billions of 1990\$)	Equity Impacts*	Legislative Authority	Major Barriers to Implementation/Enforcement	Competition	Compliance and Reporting Requirements
	Energy Use (Qbtu)	Energy Savings (Qbtu)						
No Action	443.49	0	None	None	***	None	None	None
Tax Credits (Consumers)	439.78	3.71	6.44	Some costs will be borne by all taxpayers regardless of purchase of energy efficient product	No	None, other than legislative	May favor large manufacturers	Could be unwieldy
Tax Credits (Manufacturers)	442.78	0.71	0.96	"	No	Enforcement problems likely	"	"
Rebates (Consumers)	438.97	4.52	8.95	"	No	Potential difficulties in administration	"	"
Prescriptive Standards	389.19	54.30	117.75	None	No	Restricts development of innovative technology	May reduce number of models and competition	Minimal reporting but extensive testing
Voluntary Energy	5-yr delay	387.97	55.52	None	No	No assurance that participation will be widespread	None	None
Efficiency Targets	10-yr delay	398.42	45.07					
Enhanced Labeling and Consumer Education	441.83	1.66	2.86	None	Yes	None	None	Minimal
Performance Standards	379.38	64.11	135.96	None	Yes	None	Not anti-competitive	Reasonable

Key: None = 0 or not significant

Qbtu = 10¹⁵ Btu of energy or one quadrillion Btu
(1kwh)= 11,500 Btu)

Notes: *Economic well-being of nation as a whole.

**Interpreted to apply only to regulatory programs, not as a measure of effectiveness

***Yes, if no standard is justified

As a means of achieving the level of energy savings believed possible under the proposed standards, the labeling effort by itself, or in conjunction with a consumer education program, is expected to have only a moderate effect. According to studies performed in support of the Consumer Product Energy Efficiency Program, consumers can be expected to use the label, together with a number of other criteria, to make their purchase decisions. However, the studies also indicate that there will be significant variations in consumer attitudes, depending on certain product-specific factors. (2)

2.2.3 Existing Mandatory Standards

Before the passage of the National Appliance Energy Conservation Act of 1987 (NAECA), several states established programs that set minimum efficiency levels for certain consumer products and/or set prescriptive standards through the adoption of ASHRAE standards. These programs have changed the distribution patterns for efficient appliances which has impacts at the national level. Full compliance with the mandatory standards in NAECA is expected to be on schedule.

2.2.4 Quantitative Description

The base case includes the following assumptions about factors likely to increase residential energy efficiency:

- In real terms, commercial electricity prices are projected to increase at 1.1% per year until 1995, then decline at 0.9% per year until 2000, and then increase at 0.4% per year until 2005. After 2005, commercial electricity prices are projected to rise at 0.3% per year;
- Residential electricity prices are projected to increase at 0.6% per year until 1995, then decline at 0.5% per year until 2000, and then increase at 0.4% per year until 2005. After 2005, residential electricity prices are projected to rise at 0.6% per year;
- Residential natural gas prices are projected to rise at 1.3% per year until 1995, then at 1.5% per year until 2000, and then at 4.1% per year until 2005. After 2005, natural gas prices are projected to rise at 2.2% per year;
- Distillate prices are projected to decline at 0.9% per year until 1995, then increase at 0.9% per year until 2000, and then rise at 2.5% per year until 2005. After 2005, distillate prices are projected to rise at 1.3% per year;
- The FTC labeling program for consumer products will continue;
- The DOE's existing public information program, designed to inform consumers about the advantages of purchasing more energy-efficient products will continue;

- Manufacturers will be able to produce the more energy-efficient equipment demanded by consumers;
- NAECA will be effectively implemented, at the levels proposed;
- Thermal integrity of homes is projected to continue to improve as energy prices increase;
- Appliance purchase decisions will be based on operating expenses as well as on equipment price. Appropriate weights for these are determined empirically.

The base case as quantified by the forecasting models shows that cumulative energy demand for eight products from 1996 to 2030 will be 443 QBtu.* There are no energy savings associated with the base case.

The present value (in 1990 dollars, discounted at 4% real) of new appliances (eight products) purchased from 1996 to 2030 in the U.S. is projected to be \$1,422 billion, of which \$493 billion represents equipment prices and \$929 billion represents energy expenses.

2.3 Tax Credits to Consumers

2.3.1 Discussion

The Energy Tax Act of 1978 (PL 95-618) provided a homeowner with a tax credit of up to 15% of \$2000 for the installation of energy-saving materials and equipment. This tax credit could have been used by the taxpayer in one year or over a number of years, but it could not exceed \$300 for a given residence.

Tax credits for appliances would require new legislation that would include all covered products. The use of similarly structured tax credits for the purchase of energy-efficient appliances is apt to have only a marginal effect because the size of the credit would be modest in most cases. The costs of such a program would be borne by all taxpayers because it would result in less tax revenues to the government.

Tax credits alone affect only the demand for consumer products. There is no guarantee that manufacturers will respond properly to consumer needs by producing more efficient consumer products. Thus, without a complete approach to alleviate existing market imperfections, it is doubtful that tax credits could achieve significantly larger energy savings than would occur with the no-action alternative.

2.3.2 Quantitative description

A program offering a tax credit of 15% of the increased cost of higher energy efficiency of consumer products was evaluated. This program might be more easily administered than a

rebate program because it can be carried out through an existing organization, the Internal Revenue Service (IRS). The program as evaluated here would return to a participating consumer exactly the same amount of money as the rebate program described in Section 2.5 below. The most important difference to the consumer between rebate and tax credit programs is that a rebate can be obtained quickly whereas a tax credit is delayed until income taxes are filed or a tax refund is provided by the IRS. This difference means that middle- and low-income purchasers, who generally have little ready cash to purchase more expensive products, are not as likely to take advantage of a tax credit program as are upper-income purchasers. To simulate this impact, DOE has assumed that only 60% of consumers would purchase more energy-efficient products as a result of the tax credit program. The forecast results show energy savings of 0.90 QBtu for the consumer tax credit program alternative. The net present value (in 1990 dollars), discounted at 4% real, is \$0.72 billion.

2.4 Tax Credits to Manufacturers

2.4.1 Discussion

DOE examined the possibility of providing tax credits to manufacturers. This approach would allow manufacturers to recoup some of the costs of manufacturing more energy-efficient consumer products. In combination with tax incentives or rebates for consumers, manufacturer tax credits could correct some of the market imperfections resulting from focusing only on incentives to consumers. However, the timing of a dual program for manufacturers and consumers would have to be precise to ensure that maximum benefits are achieved.

In any event, the potential would exist that many manufacturers would not respond to tax incentives. The cost of a manufacturer tax credit program could be very high. A tax credit program that would attract a high manufacturer participation rate could have very large costs. Also, the strictness of energy efficiency requirements for receiving a tax credit will affect participation. Less stringent requirements will result in greater participation but limit the energy savings achieved by the program; more stringent requirements may result in reduced participation and, thus, also limit energy savings.

Therefore, although the manufacturers tax credit program has the potential for achieving energy savings, the many issues associated with optimizing the benefits need to be analyzed carefully. Some of this analysis has been performed by DOE (3) and indicates that the cost of achieving significant energy savings through a tax credit program would be very high.

2.4.2 Quantitative Description

Offering tax incentives to consumer product manufacturers was considered as an alternative to regulation. The tax incentive analyzed would be an investment tax credit for installation of machinery and tools required to produce more energy-efficient appliances.

Production of energy-efficient consumer products requires investment in some new tools and machinery. The manufacturer tax credit considered by DOE provided a 20% credit for investment in tools and machinery required to produce energy-efficient appliances. The credit would not apply to investments in other forms of tools and machinery, nor would it apply to other forms of investment such as acquisition of subsidiaries, financial instruments, i.e., stock, loans, or new construction of plants.

Because the tax credit only applies to the portion of investment going toward production of energy-efficient consumer products and not toward investment in replacement equipment, an enforcement mechanism would be needed to prevent abuse. Enforcement would probably be divided between DOE and the IRS. DOE would have to stipulate specific categories of investment subject to the credit. The IRS would have principal responsibility for review of claims for the credit. Investigation of alleged violations would probably require joint action by DOE and the IRS. The cost of the enforcement program was not investigated, but it is thought to be high; the program would probably not be cost-effective.

The effect of the investment tax credit is to lower the cost of design options requiring new tooling and machinery. Consumer prices were lowered in the forecasting models consistent with the lower manufacturer cost. Many design options are not affected, and those that are affected are the more expensive (and more efficient) designs. The effect on consumer purchase decisions is minimal, according to the forecasting models.

Estimated energy consumption under this alternative increases by 0.01 QBTu between 1996 and 2030. The net present value (in 1990 dollars), discounted at 4% real, is \$0.22 billion.

2.5 Rebates to Consumers

2.5.1 Discussion

Providing rebates to consumers who purchase energy-efficient appliances would be difficult to implement. Although manufacturers now occasionally offer rebates as marketing tools, there is no consistent or large-scale model for a nationwide program. The concept of government-mandated rebates would entail complex interference in the market place; decisions would need to be made on which products should qualify, amount of rebate, time period covered, etc.

The rebate concept could be coupled with a tariff, much like the proposed "gas-guzzler tax" for automobiles; consumers who purchased inefficient units would be charged a federally imposed tax. It would be a costly, unwieldy, and cumbersome program to implement. However, it may be more effective than the no-action alternative.

As with tax credits, the rebate alternative will affect only the demand for energy-efficient consumer products. There will be uncertainty about the manufacturers' ability and/or desire to

respond to the demand, particularly if the rebate program is not continued over a long enough time period to account for manufacturers' lead time to produce energy-efficient products. Thus, as a separate alternative, rebates will have only a small and potentially short-term effect on energy consumption.

2.5.2 Quantitative Description

A federal program that gives consumers a rebate to encourage the purchase of energy-efficient consumer products was analyzed. This program would apply to all new consumer products whether they are replacements or for new construction. The program was assumed to provide a rebate of 15% of the increased cost of energy conservation for product efficiencies above the baseline design. The assumption of a 15% rebate has been chosen because Congress has in the past approved similar financial incentives for energy conservation retrofits of building shells and for installing renewable energy systems.

The implementation of a rebate program could be somewhat complicated because of the need to specify the exact cost of extra energy conservation in consumer products. Generally, many features are changed at one time when a new model consumer product is developed. Thus, the exact cost of increased energy efficiency may be difficult to specify. This problem could be circumvented by having the federal government set the size of the rebate for products of differing efficiencies. However, obtaining the information to establish the level of rebate for numerous products would require considerable effort to avoid arbitrary determinations. No assumption is made regarding the means of implementing the rebate (for example, through the retail store with a refund from the federal government or directly by the government).

The effect of the rebate program on residential energy consumption is simulated by reducing by 15% the incremental price to the consumer of products with efficiencies greater than the baseline model. The 15% reduction in incremental price is assumed to be paid by the federal government. The LBL-REM and EPRI-COMMEND models are run with the new price versus energy consumption curves and results are compared with the base case.

The 15% rebate program alternative results in energy savings of 1.16 QBtu between 1996 and 2030. The net present value (in 1990 dollars), discounted at 4% real, is \$1.86 billion.

2.6 Prescriptive Standards

2.6.1 Discussion

Prescriptive standards as applied to consumer products would involve specifying designs, materials, and/or manufacturing methods to achieve the desired energy use levels. For example, one requirement would be to use insulation with a specific R value in specific areas on a product. Currently, performance standards have been specified for some of the covered products. The legislative authority to set prescriptive standards for these products would have to be established.

This alternative would be fairly easy to enforce. However, it would probably result in high start-up costs and would not provide manufacturers with the necessary incentive or flexibility to increase product efficiencies or to reduce costs through innovative designs and use of new technologies. It is also highly likely that competition in the consumer product industry could be severely limited by prescriptive standards because of design constraints. This lack of competition could result in higher product prices and an increased rate of failure for firms.

2.6.2 Quantitative Description

The cost to the manufacturer of complying with prescriptive standards is greater than or equal to the cost of complying with performance standards for similar efficiencies if manufacturers are able to find more cost-effective ways of meeting the performance standards than those assumed by DOE in developing the performance standards.

There are two major disadvantages to the prescriptive approach: (1) manufacturers are given no flexibility in meeting the standards; thus, innovation in product design is likely to be substantially reduced or stifled; and (2) the certification of compliance may be ineffective because the efficiency of most consumer products depends on how the components are integrated into the product. As a result, individual components could meet prescriptive standards while overall product performance could be lower than would be true if it had to meet energy performance standards. These two effects are simulated in the LBL-REM and EPRI-COMMEND models by assuming that prescriptive standards will achieve smaller efficiency improvements than performance standards in the same time frame.

Cumulative energy savings from 1996 to 2030 are estimated to be 2.04 QBtu. The net present value (in 1990 dollars), discounted at 4% real, is \$2.12 billion.

2.7 Voluntary Energy Efficiency Targets

2.7.1 Discussion

EPCA called for industry to meet voluntary energy-efficiency targets for the covered products. If industry did not meet the voluntary targets, provisions were made for establishing federal standards. In amending the Act, NECPA, Congress specifically changed the legislation to provide for immediate establishment of federal standards to ensure the timely manufacture of energy-efficient consumer products. Although it is possible that voluntary targets might have been as effective as mandated performance standards in achieving the energy-savings goals, there probably would have been a considerable time lag because of the many uncertainties associated with a program requiring concurrence from so many participants as well as uncertainties about future consumer demand for energy-efficient products.

2.7.2 Quantitative Description

It is assumed for analysis purposes that the voluntary program would specify the energy-efficiency levels of the performance standards as goals. A fully voluntary program is assumed to cause a 10-year delay in achieving the energy conservation goals of the proposed standards. If these goals are achieved earlier in the base case for specific consumer products, then the voluntary program and the base case are assumed to be identical for these products. A voluntary program that is made mandatory if the goals are not met is assumed to achieve the energy efficiencies of the performance standards with a 5-year delay. Thus, the effects of a voluntary program are bounded by the assumptions of a 5- to 10-year delay.

The effect of this alternative in total energy savings between 1996 and 2030 ranges from 1.56 QBtu (5-year delay) to 0.90 QBtu (10-year delay). The net present value (in 1990 dollars), discounted at 4% real, ranges from \$0.86 billion (5-year delay) to \$0.53 billion (10-year delay).

2.8 Enhanced Consumer Education and Labeling Programs

2.8.1 Discussion

DOE considered expanding the current consumer education program and the FTC labeling program as an alternative to the approach mandated by Congress. The labeling program was reviewed for possible improvements or expansion beyond the current scope. An expanded enforcement program was identified as a potential improvement to the existing program. The current enforcement program relies on consumers' and other interested parties' complaints to identify non-compliance. An expanded program could more actively pursue the identification of non-complying manufacturers and retailers.

DOE similarly reviewed the current consumer education program. The consumer product education program developed by DOE sponsored 10 regional workshops for industry, educators, utilities, and state energy officials in 1979. A national consumer awareness campaign began in May 1980 to alert consumers to the appearance of the consumer product labels and to demonstrate the use of labeling information in the purchase of energy-efficient products. A consumer information booklet, public service announcements for radio and TV, educational exhibits, and a training package for retail salespersons were among the components of this nationwide effort.

The education program could be enhanced in several ways. The amount of information provided to consumers could be expanded to include product-specific information about the energy-efficient operation and maintenance of the covered products. A more active approach to reach potential consumers before they purchase products would involve increased publicity, which would require additional expenditures for media advertising and producing suitable advertisements. The advertising campaign should probably be supplemented with additional information in mailers or toll-free hot lines to answer specific consumers' questions. Finally, the

education program could be expanded to other parties involved in the purchase of the covered products, such as builders and retailers.

An enhanced education program could be expected to increase consumer demand in proportion to the amount of money spent on publicity and dissemination of information. This approach, as with the financial incentives to consumers, does not address the supply side of the marketplace equation, and, therefore, could result in less-than-optimal energy savings because of potential supply and demand inequalities.

2.8.2 Quantitative Description

Evaluating the expansion of the Consumer Education and Labeling Program requires that assumptions be made about the number of persons reached by the expanded program and to what extent the information received will influence their purchase of more energy-efficient consumer products. The program is defined, for purposes of analysis, as being able to reach an average of 10% of the purchasers of consumer products per year. These purchasers will be encouraged to use life-cycle cost techniques for selecting consumer products. Sources of information that will enable consumers to make life-cycle cost decisions will be identified.

The average purchaser reached by the program will reduce his or her discount rate by 50% (reducing the discount rate by 50% means that the purchaser will double the length of time normally considered acceptable to recover the initial higher cost of the product) for those products purchased directly by the user. For purposes of analysis, the reduction in discount rate (increase in acceptable payback period) is distributed equally among all consumers.

In general, a substantial expansion of a government consumer information program is likely to reach a relatively small percentage of the purchasing public. It will not influence those who either have insufficient funds or would not benefit enough to purchase more efficient equipment.

The variables in determining whether a purchaser of consumer products will respond positively to information presented by the programs cannot be assessed with any degree of confidence. Response is highly dependent on the purchaser's ability to comprehend the information, agree with the concepts that are presented, gather needed information, and want and afford to make the purchase. The quantitative description does not attempt to estimate this response. It merely assumes that those reached will respond positively by purchasing the most energy-efficient products (in terms of life-cycle costs) for their particular needs. Thus, the energy savings identified by the LBL-REM will often be overestimates of the response to the program because not all purchasers reached can be expected to respond positively.

Analyzing the effects of the expanded consumer product information program involved changing the implicit discount rates in the LBL-REM to simulate the program impacts stated above. For this alternative, total energy savings from 1996 to 2030 are 0.01 QBTu and these savings have a net present value (in 1990 dollars, discounted at 4% real) of \$0.01 billion.

2.9 Performance Standards

2.9.1 Discussion

The only alternative that fully complies with the Act is the setting of energy-efficiency or performance standards. This alternative is being used in the proposed regulation.

The standards will establish the maximum energy consumption or minimum efficiency level permitted for each product class but will not prescribe the means by which that level is to be achieved. The efficiencies are specified in ratios relating the output of a product to its energy use. The standards levels vary among product classes, depending on the design limitations of each class. The standards levels are based on test procedures developed by DOE, which it intends to modify on a continuing basis, to accommodate new product designs.

Performance standards will allow manufacturers the flexibility that prescriptive standards do not. Also, performance standards must be viewed in conjunction with labeling and consumer education/information programs because of the requirements in the Act. Labeling and consumer education will ensure that purchasers are aware of the benefits accruing from the purchase and use of the more energy-efficient products; in the long term, they encourage the manufacture and purchase of even more energy-efficient products than required by the proposed standards. In this context, the proposed standards provide a balanced approach to regulating the manufacture and purchase of efficient consumer products that cannot be achieved by any other alternative or group of alternatives. This balanced approach will ensure that the regulation corrects both the demand- and supply-side market imperfections and that energy savings will be realized.

2.9.2 Quantitative Description

Performance standards were quantified by assuming that all products would comply with the standards as proposed. That is, all manufacturers would meet the deadlines for the 1993 efficiency or energy consumption levels, and, after existing stocks of non-regulated products are depleted, only products meeting the proposed standards would be distributed in commerce. Maximum benefits do not accrue immediately, however, because the standards do not require retrofitting of existing consumer products, so it will take some time to replace all non-regulated products with regulated products.

The implementation of performance standards results in a total estimated energy savings of 2.26 QBtu beyond the standards set forth in NAECA. These additional savings have a net present value (in 1990 dollars, discounted at 4% real) of \$2.26 billion.

3. COSTS AND BENEFITS OF ALTERNATIVE STANDARDS LEVELS

During the development of the proposed standards, DOE considered several alternative standards levels for each product. This chapter briefly describes how the alternative levels were

selected, then presents a quantitative discussion of the costs and benefits of each of these levels to consumers, manufacturers, electric utilities, and the nation.

3.1 Choice of Standards Levels to Analyze

The analysis began with engineering estimates of the energy efficiencies associated with various design options that could meet/be specified by standards. Then, estimates were made of the added manufacturing costs that would be associated with each of the design options. After markups were applied, a consumer price associated with each of the design options was estimated.

Using the engineering estimates of the energy savings that would accrue from each design option, as well as current DOE forecasts of future energy prices, DOE estimated the value of the energy savings associated with each design option.

One measure of the effect of proposed standards on consumers is change in operating expense as compared to the change in purchase price, both resulting from standards. This measure is quantified by the difference in life-cycle cost (LCC) between the base and standards cases for the appliance classes analyzed. The LCC is the sum of the purchase price and the operating expense, including maintenance costs, discounted over the lifetime of the appliance.

The LCC for each design option in each class is calculated in the year standards are imposed using consumer discount rates of 2, 6, and 10%. The consumer price is calculated by applying a factory markup plus a distributor and retailer markup to the factory costs in the Engineering Analysis. Energy price forecasts are inputs taken from the most recent (1991) *Annual Energy Outlook* of the Energy Information Administration. Appliance usage forecasts are taken from the results of the LBL-REM and EPRI-COMMEND.

The differences in LCC between the base case and various levels of standards for the eight products are presented in Tables 6.11 - 6.13 of the TSD (1). These LCCs are calculated at a 6% discount rate (except fluorescent light ballasts, at 4%); a higher rate, e.g., 10%, gives a smaller difference; a lower rate, e.g., 2%, produces a greater difference.

When the LCC numbers are plotted (on the Y axis) against unit energy consumption (on the X axis), the data generally produce a curve that is U-shaped (see Figure E.1). This means that at first the curve will decline as efficiency improvements are made, will reach a minimum (which may or may not be discrete), and then rise. This indicates that the first efficiency improvements will produce energy savings, the value of which will more than pay for the design change. Eventually, as additional efficiency improvements are made, it becomes increasingly costly to save more energy, and the value of the energy savings will not cover the cost of the design improvement. See the TSD, Volume B through I, Chapter 2.

The standards levels that were analyzed were taken directly from the LCC estimates. One standards level that had to be examined by law was the "maximum technologically feasible" (max-tech) level.

The minimum of the LCC curve was of particular interest in the analysis. The minimum of the curve represents the level of efficiency improvements that maximizes the difference between the value of energy saved (relative to the baseline design) and the additional consumer expenditures resulting from the efficiency improvements. Therefore, design options that corresponded to the minimum point were of special consideration in establishing standards levels. The LCC minima for each product represent the levels of energy efficiency at which the average consumer's economic benefits are maximized and the burdens minimized. Efficiency levels exceeding the LCC minima were generally rejected as not being economically justified. At efficiency levels beyond the LCC minima, the first cost of an increment in the efficiency of the product exceeds the value of the energy saved, so a majority of consumers do not realize a benefit from the additional investment.

In addition to the max-tech and minimum LCC levels of efficiency for each class, DOE examined additional trial standards levels that were slightly lower in efficiency and price and correspondingly higher in consumer LCC than the minimum. Table 6 shows that eight trial standard levels were analyzed for water heaters; seven for room air conditioners; six for mobile home furnaces; five trial standard levels each were analyzed for direct heating equipment, cooktops, and ovens; four trial standard levels were analyzed for microwave ovens; three for ballasts; and three for televisions. In each case it is assumed that the standard level would be just stringent enough to induce manufacturers to use all engineering design options up through the one listed. For a more complete description of these design options see Chapter 1 in each (product- specific) volume of the TSD.

3.2 Impacts on Consumers

The major cost to consumers of stricter energy-efficiency standards is an increase in the purchase price of new products, as shown in Table 6.

The higher purchase prices of more efficient products are offset by reduced expenditures on fuel and electricity. The net benefit to consumers is summarized in Table 7, which shows the present values of the life-cycle costs for appliances purchased between 1996 and 2030 discounted to 1990 at a 6% real rate (4% for fluorescent ballasts).

Figure 3.1
Life Cycle Cost for a
Room A/C < 6K Btuh (with side louvers)

Table 6 Projected Purchase Prices in 1996 for Average New Appliances (1990 Dollars)

Appliance	Base	1	2	3	Standards 4	Level 5	6	7	8
Elec water heater	289	290	310	627	660	660	1100	1100	1100
Gas water heater	334	334	335	339	339	356	356	396	1183
Oil water heater	739	739	758	857	857	992	992	992	2241
Room Air Conditioners	479	480	485	492	496	521	561	765	
Gas Mobile Home Furnaces	594	596	627	729	816	1112	1694		
Oil Mobile Home Furnaces	1822	1825	1825	1840	1840	2093	2806		
Room Heaters	1057	1062	1122	1175	1381	1826			
Electric Cooktops	197	197	201	206	258	295			
Gas Cooktops	220	222	333	388	388	388			
Electric Ovens	508	511	519	544	557	762			
Gas Ovens	533	536	550	576	582	706			
Microwave Ovens	186	192	193	195	211	233			
Pool Heaters	1297	1384	1511	2322	3137				
Fluorescent Ballasts	16	21	24	25					
Color TV	361	363	366	379					

Table 7 Life-Cycle Cost Differences at 6% Discount Rate (1990 Dollars) (at 4% for Fluorescent Ballasts)

	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
Water Heaters								
Elec water heater	70.4	81.0	974.9	1024.2	1024.2	908.0	908.0	908.0
Gas water heater	NA	19.1	29.8	29.8	-3.8	-3.8	-13.1	-437.4
Oil water heater	134.4	29.9	93.3	93.3	1.7	1.7	1.7	-1107.8
Inst water heater	NA	NA	NA	94.2	94.2	94.2	-33.7	-1040.5
Room Air Conditioners								
up to 6K with louvers	38.9	38.9	54.7	56.7	53.5	43.5	-86.1	
up to 6K w/o louvers	31.5	31.5	55.2	59.3	56.2	47.0	-81.4	
6-8K with louvers	31.1	31.1	17.8	17.8	13.3	6.5	-150.6	
6-8 K w/o louvers	NA	11.0	12.1	12.1	9.3	3.3	-152.8	
8-14K with louvers	NA	33.7	40.4	40.4	50.1	42.6	-85.3	
8-14K w/o louvers	NA	24.2	35.5	35.5	42.4	37.7	-87.3	
14-20K with louvers	NA	81.2	81.2	86.6	126.1	126.1	10.3	
14-20K w/o louvers	NA	83.4	83.4	83.1	136.8	136.8	20.3	
over 20K with louvers	NA	0.0	0.0	100.4	139.5	165.9	48.5	
over 20K w/o louvers	NA	0.0	0.0	86.7	136.5	178.6	66.1	
HP, rever. with louvers	NA	78.5	78.5	75.5	118.8	81.5	-120.5	
HP, rever. w/o louvers	NA	26.5	34.8	34.8	36.0	13.2	-178.3	
Mobile Home Furnaces								
Gas-fired MHF	100.8	210.1	96.8	108.2	239.2	-154.1		
Oil-fired MHF	167.6	167.6	201.5	201.5	170.1	-193.3		
Direct Heating								
FW<42k	0.0	0.0	0.0	-38.3	-370.8			
FW>42k	0.0	0.0	0.0	-9.2	-294.3			
FF<37k	86.5	20.3	53.3	-276.5	-5788.4			
FF>37k	201.1	219.5	219.5	75.5	-124.6			
GW<10k	0.0	0.0	0.9	0.9	-572.0			
GW<12k	22.6	22.6	5.1	-65.2	-506.9			
GW<15k	28.4	28.4	15.3	-48.8	-494.4			
GW<19k	35.6	35.6	17.2	-241.8	-459.6			

**Table 7 Life-Cycle Cost Differences at 6% Discount Rate (1990 Dollars)
(at 4% for Fluorescent Ballasts) Cont'd**

GW<27k	51.9	29.3	28.1	-177.5	-356.1
GW<46k	79.3	23.3	41.6	-132.4	-296.3
GW>46k	104.5	48.8	59.9	-120.0	-446.7
RH<18k	48.0	7.7	7.7	-32.7	-368.2
RH<20k	25.2	16.2	5.5	-151.8	-307.7
RH<27k	49.8	49.8	49.8	-142.3	-322.7
RH<46k	68.8	17.2	17.2	-51.3	-182.9
RH>46k	65.6	46.7	46.7	22.0	-161.0
Cooktops					
Elec Coil	NA	5.7	1.6	1.6	1.6
Elec Smooth	NA	NA	NA	-550.1	-342.9
Gas	9.0	66.1	18.0	18.0	18.0
Ovens					
Elec Non-SC	27.3	38.1	53.2	53.2	-61.4
Elec Self Clean	NA	2.9	14.3	11.8	-163.7
Gas Non-SC	73.1	42.1	26.4	26.4	-59.8
Gas Self Clean	NA	4.4	7.2	2.3	-206.9
Microwave Ovens	14.1	14.8	14.1	0.0	-20.3
Pool Heaters	231.1	198.9	-447.2	-1177.6	
Fluorescent Ballasts					
1 Lamp F40	0.9	18.5	18.5		
2 Lamp F40	7.5	30.2	30.2		
2 Lamp F96	72.9	72.9	72.9		
2 Lamp F96 HO	141.6	141.6	141.6		
3 Lamp F40	11.2	63.7	63.7		
4 Lamp F40	14.8	73.6	73.6		
1 Lamp F32 T8	0.9	12.6	10.2		
2 Lamp F32 T8	7.4	22.0	29.0		
3 Lamp F32 T8	11.1	45.7	57.4		
4 Lamp F32 T8	14.7	41.1	59.4		
Color TV	11.0	14.5	24.1		

More details on the impacts of the proposed standards on consumers can be found in Chapter 3 of Volumes B through I of the TSD.

3.3. Impacts on Manufacturers

The costs and benefits of standards at various levels of stringency are summarized in terms of long-run changes in shipments, prices, revenues, net income, and return on equity (ROE). These quantities are shown in Tables 8 to 16 for fluorescent light ballasts, televisions, room air conditioners, kitchen ranges, microwave ovens, water heaters, pool heaters, direct heating equipment, and mobile home furnaces, respectively. The first column in the tables gives the value of each variable in the base case. This case represents the state of the industry in the mid-1990s if the current NAECA standards remain unchanged. Each of the next columns shows the estimated state of the industry in 1996 if one of the trial standards levels is implemented.

Each column of the tables gives the estimated values of the five most important output variables. Under each of these five values can be found two percentages. The upper tells how much the variable has changed from the base case and the lower gives the standard error (S.E.)

of the variable's estimated value. For all variables except ROE, the change is given as a percentage change. For ROE, which is already a percentage, a simple difference is given.

Except for the most stringent standards levels, manufacturers of all eight products show small changes in profitability at all levels of standards. These changes in ROE are estimated to be less than one percentage point. Although shipments decline at the highest standards levels considered, the higher selling price of efficient units more than compensates for this decline. Thus, there are increases in revenues and net income at these levels. Chapter 5 of Volumes B through I of the TSD contains a detailed description of the impacts of standards on manufacturers for their respective products.

Table 8 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.		6.66%	10.34%	10.50%

Table 9 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%

Table 10 Room Air Conditioner: Primary Scenario - Long Run

OUTPUT Table		ROOM AIR CONDITIONERS						
Scenario = Primary		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%

Table 11 Kitchen Ranges and Ovens (Excluding Microwave Ovens): Primary Scenario - Long Run

OUTPUT TABLE		KITCHEN RANGES & OVENS				
Scenario = Primary		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 12 Microwave Oven Output Table: Primary Scenario - Long Run

OUTPUT TABLE		MICROWAVE OVENS				
Scenario = Primary		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%

Table 13 Water Heater Output Table: Primary Scenario - Long Run

	1996 BASE	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
Shipments (in Mil)	1.43	1.43	1.43	1.38	1.38	1.21	1.20	1.09	1.38
% change		0.04%	0.04%	-3.22%	-3.39%	-15.32%	-16.09%	-23.53%	-3.23%
S.E.		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Price	\$131.82	\$132.13	\$134.58	\$229.31	\$236.61	\$419.42	\$435.71	\$636.44	\$234.00
% change		0.24%	2.09%	73.95%	79.49%	218.17%	230.53%	382.80%	77.51%
S.E.		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Revenue (in \$M)	187.89	188.41	191.90	316.33	325.81	506.20	521.14	693.72	322.77
% change		0.27%	2.13%	68.36%	73.40%	169.41%	177.36%	269.22%	71.79%
S.E.		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Net Income (in \$M)	0.21	0.21	0.22	0.45	0.44	0.90	0.97	1.07	0.44
Difference		-0.00	0.01	0.24	0.23	0.70	0.77	0.86	0.23
S.E.		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ROE	0.37%	0.37%	0.39%	0.79%	0.77%	1.61%	1.74%	1.87%	0.77%
Difference		-0.00%	0.01%	0.42%	0.40%	1.23%	1.37%	1.50%	0.40%
S.E.		0.18%	0.22%	2.71%	2.88%	10.39%	11.48%	17.03%	2.96%

Table 14 Pool Heater Output Table: Primary Scenario - Long Run

OUTPUT TABLE		POOL HEATERS			
Scenario = Primary		Long Run			
	1996 BASE	Level 1	Level 2	Level 3	Level 4
Shipments (in Mil)	0.02	0.02	0.02	0.02	0.02
% change		-0.47%	-1.20%	-4.47%	-7.05%
S.E		0.78%	0.90%	4.46%	4.47%
Price	\$632.66	\$678.86	\$746.05	\$1,122.86	\$1,554.06
% change		7.30%	17.92%	77.48%	145.64%
S.E.		0.59%	0.28%	7.50%	91.57%
Revenue (in \$M)	12.02	12.84	14.00	20.38	27.45
% change		6.80%	16.50%	69.55%	128.33%
S.E.		0.25%	0.81%	14.42%	69.70%
Net Income (in \$M)	1.03	1.10	1.23	1.91	2.64
Difference		0.07	0.20	0.88	1.61
S.E.		0.03	0.02	0.38	2.94
ROE	17.93%	18.72%	20.11%	25.97%	29.89%
Difference		0.79%	2.18%	8.04%	11.96%
S.E.		0.50%	0.45%	5.54%	30.85%

Table 15 Direct Heating Equipment Output Table: Primary Scenario - Long Run

	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	0.07	0.07	0.07	0.07	0.07	0.06
% change		0.31%	0.38%	0.82%	-7.81%	-16.14%
S.E.		1.51%	8.59%	16.66%	17.56%	45.80%
Price	\$220.16	\$221.65	\$238.16	\$249.73	\$332.65	\$453.66
% change		0.68%	8.17%	13.43%	51.10%	106.06%
S.E.		0.70%	3.19%	4.59%	16.33%	35.25%
Revenue (in \$M)	16.30	0.68%	17.70	18.64	22.70	28.16
% change		0.70%	8.59%	14.36%	39.29%	72.80%
S.E.		1.51%	9.21%	18.65%	25.05%	89.70%
Net Income (in \$M)	0.56	0.57	0.57	0.57	0.53	0.48
Difference		0.00	0.00	0.01	-0.04	-0.09
S.E.		0.04	0.27	0.31	0.33	1.39
ROE	7.38%	7.39%	7.38%	7.32%	7.35%	7.10%
Difference		0.02%	0.01%	-0.05%	-0.02%	-0.27%
S.E.		0.17%	0.69%	1.04%	4.33%	7.00%

Table 16 Mobile Home Furnace Output Table: Primary Scenario - Long Run

	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5	Lev 6
Shipments (in Mil)	0.06	0.06	0.06	0.06	0.06	0.07	0.06
% change		0.43%	0.81%	0.32%	0.81%	2.16%	-3.44%
S.E.		1.56%	2.40%	3.92%	10.70%	119.15%	93.52%
Price	\$245.41	\$246.91	\$252.88	\$288.79	\$294.53	\$355.23	\$565.66
% change		0.61%	3.04%	17.68%	20.02%	44.75%	130.50%
S.E.		2.43%	3.37%	7.86%	8.18%	13.95%	41.75%
Revenue (in \$M)	15.78	15.94	16.39	18.63	19.09	23.33	35.12
% change		1.05%	3.88%	18.05%	20.98%	47.88%	122.57%
S.E.		2.63%	4.03%	8.26%	14.94%	155.09%	214.41%
Net Income (in \$M)	0.51	0.51	0.51	0.51	0.51	0.52	0.55
Difference		0.00	0.00	0.00	0.00	0.01	0.04
S.E.		0.02	0.04	0.05	0.15	2.08	1.64
ROE	7.30%	7.25%	7.22%	7.18%	7.22%	6.09%	6.79%
Difference		-0.04%	-0.08%	-0.12%	-0.08%	-1.21%	-0.51%
S.E.		0.16%	0.27%	0.44%	0.58%	1.81%	3.32%

3.4 Impacts on Electric Utilities

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. This section summarizes these effects for the eight Regulatory Impact Analysis (RIA) cases. A complete discussion of utility impacts is presented in Chapter 6 of Volumes B through I of the TSD and in Appendix E of Volume A.

Calculating lost revenues depends on assumptions about economic fluctuations, regulatory behavior, voluntary consumer conservation, and existing tiered rate structures. Rate structures differ widely among utilities, and they are frequently changed by regulatory agencies, which makes calculating lost revenues difficult. In general, rate structures are adjusted so that utilities recover operating costs and receive some rate of return on investments. Furthermore, these lost revenues represent a transfer payment between the utility and its customers, so they are a cost to the utility and a benefit to the ratepayers, but they are not a true social cost. Because of the difficulty of calculating them accurately, gross utility revenue losses are estimated by the reduction in consumer electricity expenditures.

Gross revenue losses are largely offset by avoided costs. Avoided costs have three components: avoided energy costs resulting from the reduction in electricity generated, avoided reliability (generating capacity) costs resulting from the reduction in peak loads, and avoided T&D capital costs resulting from the reduction in peak loads. Avoided costs are calculated

separately for standards on heating, cooling, and baseload appliances because of the differential seasonal and time-of-day effects of these appliance groups on energy and peak loads.

Table 17 summarizes utility impacts for the eight Regulatory Impact Analysis cases, including the gross change in revenue, the net change in revenue, peak demand savings, and capacity savings. Changes in revenues are simple, undiscounted sums over the 1996 to 2030 period. Peak demand savings and capacity savings are shown for 2000, 2015, and 2030.

Table 17 Impacts of Different RIA Cases on U.S. Electric Utilities

	Case	Case	Case	Case	Case	Case	Case	Case
	1	2	3	4	5	6	7	8
Cumulative gross change in revenues 1996-2030 (B 1990\$)	-25.6	-5.2	-34.0	-346.8	-349.4	-285.8	-19.2	-397.0
Cumulative net change in revenues 1996-2030 (B 1990\$)	-4.2	37.0	417.3	-35.1	-24.0	-9.0	-1.8	-40.4
Peak demand savings (GW) 2000	1.22	0.19	2.48	12.50	3.84	-0.62	0.77	15.04
2015	2.33	0.44	3.95	27.56	32.37	27.60	1.97	32.45
2030	1.84	0.35	3.17	28.72	35.82	35.93	2.22	34.33
Capacity Reductions (GW) 2000	1.46	0.23	2.97	15.01	4.61	-0.75	0.92	18.05
2015	2.80	0.53	4.74	33.07	38.84	33.13	2.37	38.94
2030	2.20	0.42	3.81	34.47	42.98	43.11	2.67	41.20

3.5 National Impacts

3.5.1 Energy Savings

Standards for the eight products result in energy savings for the period 1996-2030. Cumulative energy savings are shown in Table 18. All savings are expressed in primary energy units (with electricity at 11,500 Btu/kWh), and include fuel-switching and behavioral (usage) effects.

Table 18 Cumulative Energy Savings 1996-2030

Product	Range of Savings by Standard Level
Direct Heating Equipment	0.04 Q in level 1 to 0.38 Q in level 3
Mobile Home Furnaces	0.02 Q in level 1 to 0.11 Q in level 5
Room Air Conditioners	0.28 Q in level 1 to 4.28 Q in level 7
Cooktops	0.01 Q in level 1 to 3.04 Q in level 5
Ovens	0.69 Q in level 1 to 3.88 Q in level 5
Microwave Ovens	0.46 Q in level 1 to 0.84 Q in level 5
Pool Heaters	0.07 Q in level 1 to 0.78 Q in level 4
Water Heaters	0.09 Q in level 1 to 54.45 in level 8
Televisions	0.52 Q in level 1 to 3.31 Q in level 3
Ballasts	13.74 Q in level 1 to 16.97 in level 3

1Q = 10^{15} primary (For electricity 11,500 Btu = 1 kWh)

3.5.2 Net Present Value of Standards

The net present value 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. That difference is then multiplied by the standards case shipments between 1996 and 2030. The net present value to consumers is calculated using a discount rate of 4% and average electricity prices for these products. Table 19 displays the net present value of standard consumers.

3.5.3 Environmental Impacts

The main environmental concern addressed here is emissions from fossil fuel-fired electricity generation. Most of the standards levels for room air conditioners, water heaters, direct heating equipment, mobile home furnaces, cooking appliances, pool heaters, fluorescent ballasts, and televisions decrease electricity use and, therefore, reduce power plant emissions. The Environmental Assessment Document (4) contains a complete discussion of the environmental impacts of proposed standards for the eight product types.

Power plant emissions include oxides of nitrogen and sulfur as well as carbon dioxide (NO_x , SO_2 , and CO_2 , respectively). The first two are major causes of acid precipitation, which can affect humans by reducing the productivity of farms, forests and fisheries, decreasing recreational opportunities, and degrading susceptible buildings and monuments. CO_2 emissions contribute to raising the global temperature via the "greenhouse effect." The long-term consequences of higher temperatures may include perturbed air and ocean currents, perturbed precipitation patterns, changes in the gaseous equilibrium between the atmosphere and the biosphere, and the melting of some of the ice now covering polar lands and oceans, causing a rise in sea level. There is strong

evidence that chlorofluorocarbons migrate to the stratosphere, break down, and catalyze the destruction of stratospheric ozone.

Table 19 Net Present Value to Society of Standards for Eight Products
(Million 1990 Dollars, Discounted to 1990 at 4% Real)

	Standard					Levels		
	1	2	3	4	5	6	7	8
Water Heaters								
Elec water heaters	328	1,441	80,109	85,866	86,042	81,320	80,968	91,949
Gas water heaters	0	100	279	278	168	172	4197	-5,851
Oil water heaters	0	272	923	919	546	562	558	-3,911
Room Air Conditioners	872	1,673	3,291	3,547	4,271	3,781	-5,556	
Mobile Home Furnaces								
Elec	0	0	-2	-3	-8	-28		
Gas	24	-269	-1,314	-2,216	-4,349	-6,030		
Oil	6	7	-6	4	-201	-2,801		
Direct Heating Equipment								
Elec	1	8	15	-11	-70			
Gas	20	166	312	-150	-983			
Oil	0	0	1	-3	-11			
Cooktops								
Elec Cooktop	0	60	-455	-9,361	-6,182			
Gas Cooktop	21	7,938	6,071	7,215	6,748			
Ovens								
Elec Oven	625	1,123	2,571	2,769	-2,337			
Gas Oven	1,964	3,475	3,182	3,197	-3,794			
Microwave Ovens	1,214	1,331	1,238	-1,071	-4,396			
Pool Heater (gas)	219	340	-1,570	-3,832				
Televisions	1,146	2,683	4,000					
Fluorescent Ballasts	22,260	25,430	27,270					

Source: LBL-REM.

Stratospheric ozone absorbs ultraviolet radiation that would otherwise reach the Earth's surface. Increases in ultra-violet radiation translate into increased risks of skin cancer in humans, adverse effects on marine and terrestrial organisms and ecosystems, and a threat of altering global climatic patterns by contributing to the greenhouse effect.

Efficiency standards on room air conditioners, water heaters, direct heating equipment, mobile home furnaces, cooking appliances, pool heaters, fluorescent ballasts, and televisions which reduce power plant emissions contribute to people's increased health and well-being. Since these impacts are difficult if not impossible to quantify in monetary terms, they are discussed in terms of reductions in gross pollutant emissions.

The proposed efficiency standards will decrease air pollution by decreasing future energy demand. When the most efficient scenarios for each product are combined, the maximum decrease of SO₂ emissions is 4.49% of U.S. power plant emissions for the year 2010. That represents a total of 378,000 tons of SO₂ abated for that year, 53.8% coming from the water heater standard (level 4), 31.3% from the fluorescent ballast standard (level 3), 6.0% from the television standard (level 3), 4.0% from the room air conditioner standard (level 5), 2.5% from the conventional oven standard (level 4), 1.9% from the microwave oven standard (level 3), 0.3% from the cooktop standard (level 2), and 0.2% from the direct heating equipment standard (level 3). There was no contribution from either the pool heater (level 2) or the mobile home furnace (level 1) standards. After the year 2000, SO₂ reductions achieved through appliance standards or any other means by those industries emitting SO₂ can be earned as credits. These are credits to emit an amount of SO₂ equivalent to the amount of the SO₂ reduction that created the credits. The new amendments to the Clean Air Act of 1990 (P.L. 101-549, November 15, 1990) allow those industries earning the credits either to sell them to others or to "bank" them for future use. Therefore, after the year 2000, to the extent that appliance standards result in SO₂ credits being earned, and to the extent that such standards-induced credits are sold and used by others, the national SO₂ reductions may not occur.

Combining the most efficient scenarios of each product, the maximum decrease in NO_x emissions is equal to 4.63% of the U.S. power plant emissions for the year 2010. This represents 338,000 tons of NO_x abated for that year, 53.4% coming from the water heater standard (level 4), 30.1% from the fluorescent ballast standard (level 3), 5.8% from the television standard (level 3), 3.8% from the room air conditioner standard (level 5), 3.1% from the conventional oven standard (level 4), 1.9% from the microwave oven standard (level 3), 1.5% from the cooktop standard (level 2), 0.3% from the direct heating equipment standard (level 3), and 0.1% from the pool heater standard (level 2). There was no contribution from the mobile home furnace standard (level 1).

Another consequence of the candidate standards would be a reduction of CO₂ emissions. CO₂ from fossil fuel burning is considered an environmental hazard because it contributes to the "greenhouse effect" by trapping heat from the sun that has been

absorbed by the Earth and emitted as infrared radiation. This "greenhouse effect" is expected to gradually raise the mean global temperature. Combining the most energy efficient scenarios for each of the eight products results in a total reduction of CO₂ in 2010 of 153,036 thousand tons, which represents 4.75% of the projected total U.S. emissions for that year. Other environmental effects, such as effects on particulate emissions, related to a standards-induced decrease in electricity generation would be minor compared to effects on decreases in SO₂, NO_x, and CO₂. Reduced hot water energy use will decrease the amount of gas or oil burned within some homes, thereby decreasing combustion effects on indoor air quality.

4. ECONOMIC IMPACTS OF THE PROPOSED AND ALTERNATIVE STANDARDS

4.1 Introduction

The proposed consumer product efficiency standards will affect both consumers and manufacturers of the covered products. In addition, there will be national economic effects. Potential economic impacts to consumers are higher purchase prices for covered products and lower expenditures on energy. Manufacturers will probably experience retooling and equipment costs, changes in sales volume, and changes in sales revenue. Potential national effects include changes in gross national product (GNP), energy consumption, income distribution, and employment.

The economic analyses that were performed in support of the proposed standards studied the above effects for each class of covered products. DOE evaluated up to eight levels of standards for each of the eight products. Based on the economic analysis, the most stringent energy-efficiency level that could be economically justified was chosen for each product class. The complete economic analysis is presented in the TSD (1). A brief overview and summary of the methods and results of the economic analysis are presented in the following section.

4.2 Methodology

The economic analysis of the proposed standards focused on likely effects on consumers, manufacturers, and the nation. Tests to measure these impacts were developed and applied to each class for varying levels of regulation. The tests examined the potential of each level to cause:

- Greater consumer expenses,
- An inequitable distribution of costs and benefits among consumer groups,
- An inequitable distribution of costs and benefits among regions of the U.S.,

- No reasonable energy savings to the nation,
- Reduced profit margins among manufacturers of the products under consideration,
- An inequitable distribution of financial impacts among these manufacturers, especially small manufacturers,
- Exposure of the manufacturers to a greater risk of financial failure, and
- Reduced competition.

The LBL-REM and EPRI COMMEND programs provide the information needed to calculate consumer life-cycle costs as well as energy savings and net present benefit to the nation. The LBL-MIM calculates impacts on profitability of firms of various sizes. The results of these models were used to compare the effects of alternative regulatory scenarios and are detailed in Chapters 3 and 5 of Volumes B through I of the TSD. The remaining sections of this chapter summarize those results and discuss the national economic impacts of the proposed standards and other regulatory approaches. Equity issues are addressed in terms of differences in effects on regions and income classes and in the variation in profitability for various size firms, which could lead to a lessening in competition.

4.3 Effects of Proposed Standards on Consumers

The major effect of the proposed standards on consumers will be changes in the purchase price and energy use of products. An analysis of life-cycle costs (LCC) incorporates these two impacts. The gross benefit to the consumer from appliance efficiency standards is the reduction in LCC. LCC discounts future operating expense savings and weighs them against the increased prices of more efficient equipment. DOE performed this analysis for each product class without regulation and at each trial standard level.

No standard was proposed that had a higher LCC than the baseline unit, with the exception of gas clothes dryer. The time over which the consumer recovers the higher initial price of the more efficient appliance ranges from less than one year for gas-fired mobile home furnaces and 2-lamp F96 high-output, 3-lamp F32, and 4-lamp F40 fluorescent ballasts, to 10 years for self-cleaning gas ovens. Previous studies indicate that energy comprises a larger fraction of the expenditures of low-income households than of average households. To the extent that the proposed performance standards decrease energy costs, low-income households would enjoy greater benefit than average. On the other hand, the increased purchase price represents a disadvantage over the short term although that increase is recovered over time. To the extent that low-income households

purchase used, rather than new, appliances, this disadvantage may be small. In fact, since many low-income households are made up of renters rather than homeowners, the landlord will bear the additional equipment price and the tenant will benefit from reduced energy expenditures if the increase in equipment price is not passed through as higher rent.

4.4 Effects of Proposed Standards on Manufacturers

The effects of the proposed standards on manufacturers are analyzed extensively in the TSD. Although these results are subject to uncertainty, that uncertainty has been estimated by using Monte Carlo techniques. The analysis presented here uses results for runs done at standards level 3 for fluorescent lamp ballasts, standards level 3 for television sets, standards level 5 for room air conditioners, standards level 3 for kitchen ranges and ovens, standards level 3 for microwave ovens, standards level 4 for water heaters, standards level 2 for pool heaters, standards level 3 for direct heating equipment, and standards level 1 for mobile home furnaces. Both the estimates of change in ROE and the uncertainty of these estimates expressed in standard errors are presented in Table 20.

Table 20 Change in Profitability Due to Proposed Standards

	Ballasts	TVs	RACs	Ranges & Ovens	Micro- wave Ovens	Water heaters	Pool heaters	Direct Heating Eqmt	Mobile Home Furnaces
ROE Before	15.53%	- 1.92%	8.56%	8.63%	8.64%	0.37%	17.93%	7.38%	7.30%
ROE After	16.12%	- 2.15%	8.62%	8.68%	8.59%	0.77%	20.11%	7.32%	7.25%
Change	0.59%	- 0.23%	0.06%	0.05%	-0.05%	0.40%	2.18%	-0.05%	-0.04%
SE of Chng	10.50%	0.50%	1.00%	0.56%	0.49%	2.88%	0.45%	1.04%	0.16%

The most obvious and important trend in the structure of these industries is the continuing consolidation that has been taking place for the past 30 years. This process tends to decrease the competitiveness of the industry and is generally stimulated by the development of low profitability in certain firms (most often in smaller firms) which then become candidates for takeovers by larger, more profitable firms. Since the analysis predicts little change in profitability in these manufacturing industries, the proposed standards would probably have no effect on the consolidation trend in the industry.

Because one cannot reliably analyze the effects on individual firms that are due to difficulties that they would encounter in attempting to implement the proposed standards, the standards could cause some unpredictable shifts in market share among

firms. This would be reflected in changes in profits. However, the demand for these products are not likely to entirely disappear and the industries as a whole will certainly find a way to meet that demand profitably under proposed standards. What one firm may lose through poor strategy, another will gain. This is not different from the continuous, normal process of competition for market share.

4.5 Effects of Proposed Standards on GNP and Employment

4.5.1 Overview

Standards will cause a shift in demand for final goods because consumers will be induced to spend more on appliances and less on energy. This in turn will cause the suppliers of these goods to spend more or less on capital, labor, and intermediate inputs. These demand changes will not cancel each other out because they will occur at different times and because the decreases in demand will eventually outweigh the increases. As a result, aggregate demand (that is, demand for goods and services by the economy as a whole) will be affected. Aggregate demand can in turn affect the level of GNP and/or the level of employment. But the translation of changes in demand to changes in output is a complex one and its analysis is subject to considerable debate among economists. The relevant theoretical considerations are discussed below.

4.5.2 Crowding Out

An increase in demand by one sector of the economy will tend to reduce demand by other sectors in two ways. The first way is through the classic crowding-out mechanism. A demand for capital goods is normally realized by means of reliance on financing from the debt and equity markets. This demand for funds causes an increase in the interest rate, which inhibits borrowing by others seeking to make capital investments. Thus, investment by one sector crowds out some investment by other sectors. Modern theory of debt markets suggests that rationing may take place, in which case some crowding out could happen directly, rather than as a result of interest rate changes.

A second type of displacement can happen in the consumer sector. If consumers are forced to spend more for one commodity, they will spend less on others. If the life-cycle cost of appliances is reduced, and consumers are completely rational and have adequate access to credit, then one would not expect any short-run decrease in consumer spending because they would fully anticipate future savings. However, the fully rational view and unlimited credit seem unlikely, and, thus, some crowding out of other types of consumption is expected in the short run. Other types of consumption are expected to increase in the long run because of lower energy expenditures. The net effect is discussed below when efficiency is considered.

4.5.3 The Multiplier

The multiplier effect is a counteracting effect to the crowding-out effect. Manufacturing firms are expected to employ additional labor after standards and the firms that supply capital goods will need additional labor to produce the required equipment, leading to an increase in employment. The newly employed workers will increase their demand for goods; this is the standard Keynesian multiplier effect. Another, more abstract view of this process, is that all realized demand becomes income and all income is divided between savings and further demand. Generally, the far larger part of income becomes demand.

4.5.4 The Rational Expectations View

Standard macroeconomic analysis has been modified by the development of rational expectations theory which points out that fully anticipated changes tend to be completely compensated for by the various economic actors. Thus, consumers who anticipate the price of a new appliance well in advance will save the same fraction of their income regardless of the actual price. Conversely, if consumers are surprised by a price increase, they may spend more and save less in the year of purchase than was planned. The result of this analysis is to predict that once the implications of standards are thoroughly understood and all parties have had time to adjust fully, the standards will have virtually no effect on the level of aggregate demand.

4.5.5 Efficiency

One effect on real GNP (but not employment) that is long-lived and not subject to the rational expectations argument is that of greater efficiency. Since standards make appliances more efficient, post-standards appliances produce a given stream of utility for a lower present value. As a result, the long-run impact of standards is to increase real GNP. This effect will be measured only if the GNP price deflator correctly reflects the efficiency gain in appliances. But whether or not it is correctly measured, this will be the only long-run effect on GNP. In other words, if the country can buy water-heating services or room air-conditioning services, etc. for less, it will spend its money on something else, resulting in the same real consumption of those services along with greater consumption of other goods.

This completes the theoretical discussion. The following sections trace the effects of changes in demand through the appliance retail sector, the appliance manufacturing sector, and the power industry.

4.5.6 Demand Effects and the Retail Sector

On appliances the typical retail markup over the wholesale price is about 1.66. This means that for an increase of \$1.00 in cost to the retailer, the consumer will be charged \$1.66. In other words, 0.66/1.66 or 40% of the increase in consumer price resulting from the proposed standards will go to retailers. This increase will occur very rapidly after the implementation date, after which demand will remain fairly constant.

4.5.7 Demand Effects and the Manufacturer Sector

Preparing for standards will require large capital expenditure, mostly before the implementation date. After implementation there will still be some increased demand for intermediate inputs and labor.

4.5.8 Demand Effects and the Energy Industry

After standards are implemented, energy demand will be reduced slowly (below the base-case level). This reduction will have a direct effect on income for the energy industry and a multiplier effect as that reduced income is spent. As more efficient appliances are put in place, and the reduction in energy demand accumulates, the demand for energy-generation facilities will eventually be affected. Changes in the construction of these facilities will occur at different times in different locations, and, consequently, the effect will be spread over many years. Also, because the effect is gradual and will not reach significant proportions for several years after implementation, it should be well anticipated. Thus, rational expectations theory assures us that changes in energy demand should not affect aggregate demand.

4.5.9 Summary and Conclusions

In the short run, crowding out will be incomplete, so that aggregate demand will first increase and then return to normal. This increase will begin about three years before implementation. The peak rate of investment should occur one to two years before, when the demand for capital for retooling to meet the standards by water heater, mobile home furnace, direct heating equipment, television, kitchen range and oven, room air conditioner, pool heater, and fluorescent light ballast manufacturers would rise by several hundred million dollars per year above normal. The value of the short-run Keynesian multiplier depends on prevailing macroeconomic conditions, estimates of which vary widely, but values between one and three are typical, including crowding-out effects.

Another large increase will occur when standards are implemented because revenues in these industries are estimated to increase by approximately \$286 million per year. Again, this increase can be translated directly into a short-run increase in GNP. Demand will probably return to its original level within two or three years of the implementation of standards. This estimate is based on the view that the multiplier is a relatively short-run phenomenon, and that, in the long run, crowding out is nearly complete.

4.5.10 Trade

Standards will have virtually no effect on appliance imports. However, oil imports are essentially determined by the gap between domestic production (which is independent of demand) and the demand for oil. Thus, to the extent that standards reduce the demand for oil, the trade balance will be improved.

4.6 Impact of Alternative Regulations

This section analyzes the macroeconomic impacts of alternatives to performance standards. As with the above analysis of performance standards, the impacts are given relative to the base case of "no action". For a list of the alternatives and their non-macroeconomic impacts, see 5.

4.6.1 Tax Credits

Tax credits for consumers and for manufacturers were analyzed in sections 2.3 and 2.4 respectively. The impact will be small in proportion to the reduction in net present value (NPV) for fuel and equipment, as shown in Table 5. Thus, after implementation, the impacts should be 5% as large as those predicted for performance standards.

The impact of the manufacturer tax credit is small because the investment tax credit is applicable only to the manufacturers' tooling and equipment costs, and most of the cost of the

design options considered involve purchased parts. This analysis found that the resulting price reductions would be small and would apply to only a limited number of design options. Furthermore, because of the increase in appliance efficiencies under the 1990 NAECA standards, tax credits would induce only a small change in consumer purchases. Since very few high-efficiency appliances would be purchased, manufacturers would not choose to manufacture them. Thus, they would not invest in the necessary equipment, and, if the law were correctly enforced, would not receive large tax credits. As can be seen from Table 5, the magnitude of these effects is indeed small.

4.6.2 Consumer Rebates

A program of consumer rebates is an incentive for consumers to purchase more efficient appliances, similar to the program of consumer tax credits. The macroeconomic impact will be smaller in proportion to the reduction in net present value (NPV) for fuel and equipment, as shown in Table 5. Thus, after implementation, the impacts should be 7% as large as those predicted for performance standards.

One small distinction between the macroeconomic effect of a consumer rebate and a mandated standard can be noted. The rebate partially supplements the consumer's income, and, thus, reduces the consumer's tendency to reduce other spending because of the increased expenditures on efficient appliances. In order to analyze this program on its own terms, and not as part of a deficit spending program, one should assume the rebate is paid for with taxes. These taxes will have nearly the same crowding-out effect that the extra appliance expense would have had. So, in the end, no correction needs to be made to the original analysis.

4.6.3 Prescriptive Standards

Prescriptive standards are assumed to be implemented as standards at 1 level below the performance standards. For example, room air conditioners will be at standard level 4 instead of level 5 as in the performance standards. The lower standards level entails slightly smaller expenditures for tooling and purchased parts. Consequently, the macroeconomic impacts before the implementation date should be slightly smaller for prescriptive standards.

After implementation, the impact of prescriptive standards will be smaller in proportion to the reduction in net present value (NPV) for fuel and equipment, as shown in Table 5. Thus, after implementation the impacts should be 87% as large as those predicted for performance standards.

4.6.4 Voluntary Efficiency Targets

The macroeconomic impacts of voluntary targets will be smaller than would be indicated from the size of the NPV for fuel and equipment in the targets case. Although the NPV of the savings is between 67% and 88%, the macroeconomic impacts will be much less than these figures suggest, because the multiplier is a short-run effect, but the various forms of crowding out are long-run effects. Although the estimates must be quite rough, if the multiplier has a

half-life of two years (it is unlikely to be more), the macroeconomic impact with a five-year delay would be, at the very most, half of 88% (or 44%) of the performance standards impact. With a 10-year delay the impact would be at most one-fourth of 67% (or 16.75%) of the performance standards impact.

4.6.5 Enhanced Labeling and Consumer Education

Enhanced labeling and consumer education is not likely to be a good incentive for consumers to purchase more efficient appliances. If consumers respond as expected, the macroeconomic impact of this alternative will be much smaller in proportion to the reduction in net present value (NPV) for fuel and equipment, as shown in Table 5. After implementation, the impact is only 2% as large as that predicted for performance standards.

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