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TECHNICAL SUPPORT DOCUMENT: ENERGY CONSERVATION STANDARDS FOR CONSUMER PRODUCTS: DISHWASHERS, CLOTHES WASHERS, AND CLOTHES DRYERS

**including:
Environmental Impacts
Regulatory Impact Analysis**

December 1990

U.S. Department of Energy
Assistant Secretary, Conservation
and Renewable Energy
Office of Codes and Standards
Washington, DC 20585

MASTER

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EXECUTIVE SUMMARY

The Energy Policy and Conservation Act as amended (P.L. 94-163) 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. This Technical Support Document presents the methodology, data and results from the analysis of the energy and economic impacts of standards on dishwashers, clothes washers, and clothes dryers.

The economic impact analysis is performed in five 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 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* 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;
- A *Environmental Effects* analysis, which estimates changes in emissions of carbon dioxide, sulfur oxides, and nitrogen oxides, due to reduced energy consumption in the home and at the power plant.

A *Regulatory Impact Analysis* 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 until the year 2015. 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 impacts on individual consumers are evaluated by determining the changes in life-cycle cost (LCC) resulting from the imposition of the proposed standards. Payback periods and cost of conserved energy (CCE) are alternative measures of these impacts on individual consumers, calculated for the year in which standards are implemented.

The Manufacturer Impact Analysis estimates the overall impact of new or amended standards on manufacturers as well as the distribution of effects among firms of different size. 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). The impact of standards on competitiveness is analyzed by assessing relative changes in growth and profitability for large and small firms.

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 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. This analysis thus determines the marginal electricity costs for evaluating the benefits of the proposed standards from a societal perspective. 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.

1. INTRODUCTION

1.1 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 products* 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 standards for the three types of products 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 costs with and without the standards; a determination of change in investment, revenues and expenditures by 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.

1.2 STRUCTURE OF THE DOCUMENT

This technical support document consists of an executive summary, eight chapters and four appendices. It also includes the Regulatory Impact Analysis. The chapters cover the following topics:

Chapter 1	Introduction.
Chapter 2	Analytic Approach: summarizes the methodology used in the economic 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 3	Engineering Analysis of Design Options: presents the results of the engineering analysis showing the costs and efficiencies associated with each design option.
Chapter 4	Development of Base Case Forecasts: presents the results of the base-case forecast (under existing legislation). It also describes the base-year data and projections of exogenous variables used in the forecasting models.
Chapter 5	Results of the LBL Residential Energy Model (LBL-REM): discusses the choice of standards levels to be analyzed. The chapter summarizes the energy savings by fuel and product; the sales, average efficiencies, purchase costs, and operating costs of new and replacement appliances; and the net present benefit of the standards. The results of the sensitivity analyses are also presented.

* The 13 covered products 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.

- Chapter 6 Life-Cycle Costs and Payback Periods: describes the effects of standards on 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 7 Impacts of Standards on Manufacturers: provides an industry profile of the manufacturing firms affected; describes the effects on appliance manufacturers of imposing standards by product; summarizes 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 a sensitivity analysis of the results.
- Chapter 8 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.

Appendices A through C contain more detailed information on the models and data bases used in the economic analysis. They also present more disaggregated results than are provided in the text.

- Appendix A Engineering Analysis: provides a detailed description of appliance classes and design options. A breakdown of the costs for each design option is presented.
- Appendix B LBL-REM: gives a detailed description of the methodology and data used to calculate consumer impacts. The principal components of the LBL-REM are discussed and component interrelationship is explained. The appendix describes and defines the inputs to the model. The input data stream for the base case 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.
- Appendix D Environmental Effects: provides quantitative estimates of the emissions reductions due to standards, for carbon dioxide, sulfur oxides, and nitrogen oxides.

2. ANALYTIC APPROACH

This chapter briefly describes the way the analysis of standards was performed. The first section, an overview of the analytic methodology, discusses the major components of the analysis: the Engineering Analysis, the Consumer Analysis (National and Individual), the Manufacturer and Industry Analysis, 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.

The second section of this chapter describes the computerized models used in the analysis. The models predict consumer, manufacturer, and utility response 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
- Residential Energy Model (LBL-REM)
- Manufacturer Impact Models (LBL-MIM)
- Utility Impact Model

The function, data sources, assumptions, and validity of the results for each model are discussed. Additional details may be found in the Appendices and in the previous Technical Support Document. (1)

The third section 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.

2.1 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. These projections first are made for a base case (existing legislation) using the analytic models described below. Chapter 4 describes the data and assumptions used to calculate the baseline forecasts. The calculations are then repeated imposing the proposed standards as discussed in Chapter 5. 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 five 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-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* 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;
- A *Environmental Effects* analysis, which estimates changes in emissions of carbon dioxide, sulfur oxides, and nitrogen oxides, due to reduced energy consumption in the home and at the power plant.

A *Regulatory Impact Analysis* 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 2.1. Each type of analysis is performed for the three 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 dishwashers, clothes washers, and clothes dryers 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 5.

Figure 2.1. 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. 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 2015 because clothes dryers have a lifetime of 15 to 23 years (average 18.5 years) and the standards come into effect in 1993. 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.

Figure 2.1. Analytic Framework for the Appliance Standards Analysis

2.2 IMPACT MODELS, DATA AND ASSUMPTIONS

2.2.1 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 clothes washer is an appliance type, but a top-loading standard clothes washer is an appliance class. The Engineering Analysis develops cost and efficiency data for a set of design options within each appliance class.

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 Notice of Proposed Rulemaking. Those classes for which no DOE test procedure has been specified are omitted.

In the Proposed Rule, DOE proposed new standards for three classes of dishwashers, three classes of clothes washers, and five classes of clothes dryers. In the following chapters, three classes of dishwashers, two classes of clothes washers and four classes of dryers were analyzed. Two clothes washer product classes (top-loading standard and large) were aggregated into one class (standard) that covered the full capacity range of the original two classes. Two clothes dryer classes (gas compact and standard) were aggregated into one product class (gas). The appliance classes covered by the analysis are listed in Chapter 3.

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 NAECA. For these three products, only design standards are specified in the Act. The units chosen for baselines in Chapter 3 represent models with efficiencies somewhat higher than the least efficient models available in 1989. 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 or that are present in prototypes were considered. They were 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. The maximum technologically feasible 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 the three product types, the efficiency levels corresponding to various design options are determined from manufacturer data and from engineering calculations.

Cost estimates: The manufacturer cost data were 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 were also received in response to the Notice of Proposed Rulemaking. 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. 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 large- and medium-sized 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 the difficulty in obtaining data to model small manufacturing firms and the fact that they represent a small fraction of the total shipments for most of the product classes, analysis concentrated on the medium and large manufacturers.

- Baseline units can be selected to represent typical product offerings within a class.
- Unit energy consumption is based on DOE usage estimates, unless otherwise noted, e.g., dryers with termination by temperature or moisture sensors.

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 1989.

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, published data, and comments received on the Notice of Proposed Rulemaking.

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 factor;*
- 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 and maintenance costs.

Validation of the Results

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

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

2.2.2 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, Section B.9, for a list of changes made to the methodology or data since July, 1989.

Engineering, economic, and demographic data are used in LBL-REM. The engineering data for appliances are described in Section 2.2.1. 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 usage behavior, which includes 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. (2)

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. (3) Many of these changes have already been documented. (4) 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 are single-family, multifamily, and mobile homes. Calculations are performed separately for existing and new housing construction each year during the forecast period, 1980-2015. The end-uses are space heating (including room and central), air conditioning, water heating, refrigeration, freezing, cooking, dish washing, clothes washing, clothes drying, lighting, and miscellaneous. Up to four fuels are considered, as appropriate to each end-use: electricity, natural gas (utility gas), heating oil, and 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 2.2.

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 each year, 1981-2015, 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 1987 for dishwashers and clothes washers, and through 1980 for clothes dryers. After 1987, efficiency improvements are projected as a function of designs available (technological change) and of electricity price. 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.⁺ 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., clothes washers purchased each year, in the absence of additional federal regulations (base case). A distribution of unit energy consumptions (UEC) is constructed around the projected average UEC 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.

Turnover of Appliance Stocks. The initial age distribution of appliances in stock is characterized, based on 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.* 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 purchasers may make no purchase or may buy any competing technology within an end-use. For dishwashers and clothes washers, the decision to purchase or not is modeled, and the fraction of the total that choose each class and the fraction of the total that choose each class, e.g., for dishwashers, standard 115V; standard water heating 115V, etc, 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 cost will decrease market shares, while lower operating expense will increase market shares. The net result depends on the standards level selected, and associated equipment price and operating expense.

⁺ 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.

* For example, a cohort consists of all 12-year old dishwashers. Up to 30 cohorts, one for each year of purchase, are tracked for each product.

LBL RESIDENTIAL ENERGY MODEL

DATA:

OUTPUT:

ANNUAL ENERGY CONSUMPTION -By End Use -By Fuel -By Building Type	FUEL EXPENDITURES -By End Use -By Fuel -By Building Type	CAPITAL COSTS -By End Use -By Fuel -By Building Type
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Figure 2.2. Activities in the LBL Residential Energy Model

Usage Behavior. For some products, changing the operating expense results in changes in usage behavior. These changes are modeled using usage elasticities in operating expense and income. For dishwashers, clothes washers, and clothes dryers these elasticities are assumed to be zero.

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 unit energy consumption 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 own that appliance.**

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

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 assumed to be correct. Justifications for the most important assumptions in the Consumer Analysis are listed below.

<i>Assumption</i>	<i>Justification</i>
<ul style="list-style-type: none">Population growth is projected to follow census projections to the year 2000, and population growth is projected to slow from 2000 to 2015.	A recent 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.

** 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).

- The fraction of the population of 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 average 1,100,000 to 1,220,000 single-family units; 470,000 to 550,000 multifamily units, and 320,000 to 450,000 mobile homes.
- Real disposable personal income is projected to grow from \$3.01 trillion in 1985 to \$5.55 trillion in 2015 (in 1987 dollars). This corresponds to disposable personal income per household growing from \$36,000 in 1985 to \$54,800 in 2015.
- In real terms, residential electricity prices are projected to increase at an average annual rate of 0.1% from 1988 to 2000, and 0.2% from 2000 to 2015. Residential natural gas prices are projected to increase at an average annual rate of 2.8% from 1988 to 2000, and 0.9% from 2000 to 2015. Residential distillate prices are projected to increase at an average annual rate of 3.6% from 1988 to 2000, and 0.9% from 2000 to 2015.
- Appliance purchase decisions are based on operating expenses, as well as on equipment price.

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 (1989) provides the projection to 2000, which is extrapolated to 2015. The extrapolation is linear based on the 1995 to 2000 trend.

The DOE/EIA Annual energy outlook (1989) provides the projection to 2000. The rapid price increases projected for gas and oil for the 1990's are not expected to sustain themselves into the following 15 years.

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

- Manufacturers are projected to respond to consumer demand for energy-efficient products. Engineering designs that are technologically feasible and that would be 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.
- Industry is workably competitive and has responded historically to changes in consumer demand. No evidence suggests an end to this responsiveness.
- Increasing energy prices and increasing awareness on the part of energy consumers have resulted in modified construction practices and home retrofits. Building codes under consideration, utility company incentives, and projected long-term energy price increases suggest that further thermal improvements are likely.
- The retirement functions are based on a reconciliation of appliance stocks (measured by surveys) and appliance shipments. The lifetimes may include engineering and economic determinants, which are not separated in existing studies.

Data Sources

The LBL-REM takes 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;
- 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 1993-2015. Energy savings are provided annually from implementation of standards to the end of the period. Net present value of standards is evaluated for each regulated product, and for the end-uses(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 net present value is the sum of discounted savings in operating expense minus the sum of discounted increases in equipment prices.

DOE has determined that 7% 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 15% 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 using appliances differently. For example, if, after standards, a regulated product captures larger market share 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.

Net present value excludes these secondary effects. Base case purchase behavior, without market share changes, is assumed in calculating the net present value, because any market share shift reflects the consumer's judgment that that change is worth more than the direct energy savings associated with keeping market share constant. Net present value is calculated from per unit changes in equipment and operating costs, multiplied by standards case shipments. If the net present value were calculated without normalizing to shipments, the results would be erroneous: 1) if standards caused decreased purchases of a product, this would appear as economic benefits, namely less money spent on purchasing and using the appliance;* and 2) if standards resulted in increased purchases, this would be counted incorrectly as a cost, when it reflects consumers' preference for the post-standards product.

2.2.3 Manufacturer Impact Models

2.2.3.1 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 2.3 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.

* 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 net present value of standards.

2.2.3.2 Measures of Impact

Three types of long-run impact are analyzed: 1) profitability, 2) growth, and 3) competitiveness. To do this, five measures of impact are tracked for the industry as a whole and for any segments that may exist. The five impact variables are: 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 appliance industries are in a 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.

2.2.3.3 Description of the LBL-MIM

Although the manufacturer impact model, 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. A decrease in operating cost 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 cost 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 one more calculation to correct for 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 only be understood in light of the following standard economic consideration. In the long run, an increase in *fixed costs will not be passed on* in the form of a price increase, except when it is sufficient to cause some firms to leave the industry.* 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 Section C.2.1.

A second influence on profits is the change in demand resulting from both the change in price and the change in operating cost. These tend to offset each other because the price increase weakens demand, and the increased efficiency, which results in lower operating cost, strengthens it. 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 scrutinized in the sensitivity analysis.

* 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.

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 assumption. This is followed by a list of more detailed assumptions.

The long run. 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, they 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 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 which 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 typical firm is modeled as if it produces 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. These divisions are also generally run on a profit-and-loss basis similar to a firm. Also, it is impossible 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 TVs, 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 Value Line, Standard and Poor's, Moody's, and publicly available company reports.

Figure 2.3. Conceptual Approach to the Manufacturer Impact Analysis

Assumption

- Firms maximize revenues minus economic costs ($R-EC$), where EC includes the cost of equity and all taxes.
- The life-cycle-cost elasticity of demand experienced by a single firm is constant. This means that price elasticity will tend to increase with price, and tend to decrease with operating cost. Note also that since price elasticity is finite, firms have market power.
- Costs are assumed to have two components: one fixed, and one proportional to quantity.
- Assets are assumed to be a linear function of sales.
- The debt-to-equity ratio remains constant while the firm finances any investment necessary to meet standards.
- The additional costs of parts, materials and labor are assumed to be long-run marginal costs.

Justification

This follows from the assumptions of standard economic theory, in which firms are rational profit maximizers.

There is no reason to assume that life-cycle-cost elasticity either increases or decreases with cost; thus, constancy is the base assumption.

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.

Same as previous justification.

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.

These costs are proportional to production except for cases in which there are discounts for larger quantity purchases. Industry sources state that at the scales of production under consideration, these discounts have been very nearly exhausted.

- 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.

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 has its effect by reducing 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 variables' long-run values at each of the standards levels under consideration. LBL-MIM also produces a simplified income statement. As part of its algorithm, it calculates the markup from manufacturer's cost to consumer purchase price. The purchase price is used in the price-efficiency curves, the life-cycle cost curves, the calculation of payback periods, and throughout the LBL-REM.

All of the above values are estimates which necessarily reflect some uncertainty. Estimates of these uncertainties and identification of their sources are 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 appears in Section C.2.5.

2.2.4 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; reduction in fossil-fuel consumption is also 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 D of the previous Technical Support Document (1) 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 D of the previous Technical Support Document. 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 kW) divided by its peak load savings. The peak savings are averaged over an on-peak period from 8 am to 8 pm. This wide on-peak period yields a conservative estimate for peak load savings that accounts for coincidence with system peak demand. The CLF for dishwashers used in this analysis is 0.76; the CLF for washers and dryers is 0.63.

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. (5) 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 dishwashers, clothes washers and clothes dryers 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 are 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 include assumptions about the shape of regional load duration curves, about factors that remain constant through the analysis, about the regional distribution of energy savings, about utility marginal costs, and about the substance of the NERC forecasts.

<i>Assumption</i>	<i>Justification</i>
<ul style="list-style-type: none">• 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.	There is little information by NERC region on which fuels are marginal. Since NERC supplies the total amount of fuel burned for generation, some way 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 greatest 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.
<ul style="list-style-type: none">• The oil and gas fractions (OGFs) calculated for all the NERC regions remain constant throughout the analysis period.	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.

- Energy savings accrue in each region in proportion to the region's consumption of heating, cooling, and baseload energy in 1980. 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.
- 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. 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. 10,000 Btu/kWh is the typical heat rate for many different types of generating units.
- The NERC forecasts of changes in adjusted reserve margin are accurate. The NERC forecasts are widely accepted. They are the only forecasts of adjusted reserve margin at the regional level.

2.2.5 Life-Cycle Cost Analysis

One measure of the effect of 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 calculated at a standard level and at the energy use projected by LBL-REM for the year the amended standard goes into effect. The LCC is the sum of the purchase price and the operating expense discounted over the lifetime of the appliance, using real consumer discount rates of 2, 7, and 15%. 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, where 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 6.

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 in the year standards come into effect and at the energy prices in that year.

2.3. SENSITIVITY ANALYSIS

Sensitivity studies are performed to determine how changes in technical and operational parameters affect key engineering and economic indicators used in evaluating 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 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 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 the LBL-MIM is conducted mainly from a sensitivity chart which reports the sensitivity of ROE to each of the nine control variables. Because the LBL-MIM is a nonlinear 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. These results are presented in Section 4.3. 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.

2.4 REFERENCES

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3. ENGINEERING ANALYSIS

3.1 INTRODUCTION

The economic impacts of new or amended efficiency standards depend largely on the relationship between the cost of a consumer product and its energy efficiency. This chapter presents the engineering basis for the cost-efficiency relationships for three products. A summary of the Engineering Analysis methodology is given in Chapter 2. More detail on the manufacturing cost data can be found in Appendix A.

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 Engineering Analysis is carried out for three classes of dishwashers, two classes of clothes washers, and four classes of clothes dryers. 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 baseline units, design options, and maximum technically feasible efficiencies is based on information gathered from the trade association, manufacturers, discussions with researchers, a literature survey, and comments on the Notice of Proposed Rulemaking (Proposed Rule). Energy data have been obtained from AHAM (Association of Home Appliance Manufacturers), manufacturers, and the FTC (Federal Trade Commission). Factory cost data obtained from individual manufacturers have been reviewed and averaged. The cost estimates are combined with the efficiency estimates to generate the cost-efficiency relationships.

The relationships between incremental factory costs and efficiency that are presented in this chapter are used throughout the other parts of the analysis. The baseline factory costs are derived from manufacturers' estimates. Incremental factory costs are added to the baseline factory cost to give the manufacturing costs of the design options presented in the Engineering Analysis. The Manufacturer Analysis uses factory costs to produce retail prices. Retail prices, in conjunction with the efficiencies presented here, are used in the LBL-REM to forecast sales and efficiencies (Chapters 4 and 5) and in the life-cycle cost and payback calculations (Chapter 6).

3.2 DISHWASHERS

3.2.1 Introduction

Changes to the Engineering Analysis since the July, 1989 TSD (DOE/CE-0267) include: a reduction in the baseline energy factor for standard dishwashers, addition of a booster heater as a design option for standard dishwashers and reduced booster heater use for water heating dishwashers.

3.2.2 Product Classes

Basic models of dishwashers are segregated into separate classes to which different efficiency standards may apply. There are no changes to the three classes of dishwashers that were established in the earlier dishwasher analysis. Table 3.1 shows the list of product classes.

Table 3.1. Product Classes for Dishwashers

1. Compact Dishwasher, 115V
2. Standard Dishwasher, 115V
3. Water-Heating Dishwasher, Standard (115V)

3.2.3 Design Options

The design options analyzed are listed in Table 3.2. The design options are changes that can be incorporated into the design of a dishwasher to improve its efficiency. Some of the options listed are found in existing products; others are being developed. It should be noted that the power dry option is found in all models presently manufactured. Therefore, it is included in the baseline model for each dishwasher class. The only change from the Proposed Rule is that the addition of an electric resistance booster heater is now considered as a design option for standard dishwashers. A booster heater can be used to raise the temperature of incoming hot water that is used for wash or rinse cycles.

Table 3.2. Design Options for Dishwashers

1. Improved Food Filters
2. Improved Spray Arm Geometry
3. Improved Fill Control
4. Modified Sump Geometry
5. Reduced Inlet Water Temperature
6. Improved Motor Efficiency
7. Increased Insulation
8. Flow-Thru Heating
9. Booster Heater

Improved Food Filters

Food filters remove food particles from the water during wash and rinse cycles, and thus, keep food from redepositing on the dishes. Improving filter design to more effectively remove food particles can shorten the duration or the number of wash and rinse cycles. The primary benefit of improved filter design is a reduction in hot water use. Any successful filter redesign must maintain washing performance. Improved food filters are currently being offered by some manufacturers.

Improved Spray Arm Geometry

Spray arms, which are typically located in the top and bottom of a dishwasher, are designed to rotate and spray pressurized water on the dishwasher contents. If the spray arms could be designed to more effectively remove food particles, dishwashers would use less hot water and energy.

The spray arm is a critical element in overall dishwasher cleaning performance and is an important sales feature. Manufacturers treat it as a highly proprietary area of research and development. A European manufacturer has developed a system to reduce water use. (1) In this system, water spray alternates from the top spray arm to the bottom spray arm, during both the wash and rinse cycles. The manufacturer's advertising states that less water is needed in the

bottom of the dishwasher with this system, but the wash quality and the wash cycle time remain the same. Data are not currently available to estimate the reduction in water consumption and energy use from such a design change.

Improved Fill Control

Modifying the fill control to admit a lower volume of water would reduce hot water consumption and energy use. This could be accomplished by reducing the safety factor presently employed by most manufacturers. Safety factors, which result in overfill for some consumers, are applied in the sump region and, also, in the timer-activated water fill to ensure enough water for proper pump action and cleaning. Typical systems use electro-mechanical timers to control fill volume. Replacement with more accurate electronic timers would maintain a tighter tolerance on the fill time period. Cost-efficiency data are presented for this design option in Section 3.2.5.

Manufacturers employ another overfill factor. Water flow rate through valves varies with water pressure, which can differ from house to house by 10 to 15%, so the use of timer controls could cause a variation in quantity of hot water delivered. Therefore, manufacturers presently use an additional overfill factor of 10 or 15% because of the range of water pressures existing in the U.S. If a pressure-activated water volume sensor were used to control water fill rather than a timer, overfill could be reduced. Data have not been obtained for this design option.

Modified Sump Geometry

The amount of water used for each cycle could be reduced by a change in the geometry of the sump. During the wash part of the cycle, approximately half of the water is in the sump to ensure an air-free water supply to the pump. Manufacturers believe that present sump design minimizes water use while maintaining an adequate water supply to the pump. An extensive literature survey did not produce any useful data on sump design. Additional research is required to optimize sump configuration and estimate energy savings.

Reduced Water Inlet Temperature

Manufacturers currently feel that 140°F water is needed to clean dishes properly. A reduction in the dishwashing temperature from 140°F would save a significant amount of energy. A detergent would have to be found that could effectively remove food particles and fats from dishes in water less than 140°F. Tests conducted by Kaneko and Compton showed that with 100°F water, four of six name brand detergents performed with good to excellent results. (2) At this time, no data are available that indicate dishes soiled with animal fats can be adequately cleaned at temperatures below 140°F.

Improved Motor Efficiency

The electric motor consumes about 8% of the energy used in a typical dishwasher. The motor runs the sump pump and the spray arms. Dishwashers typically use split phase motors because of their low torque requirement and constant starting current condition. A capacitor-type motor is more efficient than a split phase motor. It uses a capacitor in both the starting and running modes. The capacitor-type motor increases the power factor, and, therefore, reduces heating losses in the stator. An electric motor efficiency of 65% should be possible using a capacitor-type motor. If the baseline model has a motor with an efficiency of 50%, the 30% improvement will result in approximately a 2.5% overall reduction in dishwasher energy consumption.

Increased Insulation

Dishwashers generally have some insulation to reduce noise levels. Additional insulation around the tub will decrease heat losses further. However, the marginal benefit for additional insulation is very small. Testing by manufacturers has shown that increasing insulation does not allow the use of a lower water temperature. This has been confirmed by other researchers through both experimental testing and simulation modeling. (3) The same researchers found that an increase in thermal capacitance had little effect on dish temperature. They simulated a steel and porcelain tub, a plastic tub, and an aluminum tub. There was little change in the temperature of the dishware in all three cases.

Flow-Thru Heating for Water Heating Dishwasher

Water heating dishwashers are equipped with a tubular heating element at the bottom of the water tank. Water is heated there before being pumped and distributed to the spray arms. The heating element always needs to be covered with water. Therefore, during the washing cycle, when warm water is circulated to the spray arms, extra water may have to be kept in the water tank. To limit the warm water to the useful amount for a washing cycle, a new device has been developed in Germany using a flow-thru heating technique to heat the water. (4) The new heater is a metallic flow tube around which an electrical tubular resistance heater is wrapped. It is positioned outside the area where the pump is located. Therefore water is heated to the required washing temperature while being circulated to the spray arms. Consequently, less water may be required in the bottom of the dishwasher. Laboratory experience has proved the feasibility of the device. The potential water and energy savings depend upon the configuration of the sump and heater element. If the heater element is already submerged because of the pump requirement, there may not be any potential energy savings from the flow-thru heater. Data are not available to estimate energy savings of this design option for water heating dishwashers.

Booster Heater

Water heating dishwashers employ booster heaters to raise the temperature of incoming water to a pre-determined value. If a booster heater is added to a standard dishwasher, it will be equivalent to a water heating dishwasher. Since only a portion of incoming water is heated in a booster heater, it is possible to reduce energy consumption by adding a booster heater to a standard dishwasher. In that case, some water which was previously heated to 140°F will only be heated to 120°F before entering the dishwasher.

3.2.4 Manufacturer Cost and Energy Use Data

In this section, manufacturer cost, energy factor, and energy consumption data are presented for three product classes. The manufacturer cost is the cost to the manufacturer of producing products with the design options shown, and does not include any markups to wholesalers or retailers. The energy factors are equal to the inverse of the energy consumption per cycle. The energy use data are annual unit energy consumption in kWh for households with electric water heaters. Energy factors and energy use are calculated according to the DOE test procedure and with newer usage data provided by Procter and Gamble. (6) The only difference between the DOE test procedure and the new data from Procter and Gamble is that the usage is reduced from 322 to 229 cycles per year. Basic physical and engineering principles and manufacturer supplied data were used to perform the energy savings calculations.

Most of the cost data (except for booster heater) are obtained from a report by ADM Associates, Inc. (7) The data were collected from several dishwasher manufacturers and averaged in order to protect the confidentiality of data from individual manufacturers. Independent estimates of the cost of efficient electrical motors were obtained from motor manufacturers and consultants. Cost data were only received for standard-sized dishwashers. These data were extrapolated to be used for standard-sized water-heating and compact dishwashers. No changes were made to the manufacturer cost data in the Proposed Rule. These costs are expressed in 1988 dollars. Appendix A.2 contains disaggregated costs for each product class. Total costs are divided among labor, material, purchased parts, tooling and capital costs, and shipping and packaging. A description of the design options used in the final analysis follows.

Energy Use Data

Energy consumption data were obtained from several sources. AHAM provided sales weighted energy use data. For 1988, average standard water heating dishwashers (115V) and standard dishwashers (115V) consumed 2.63 kWh/cycle (EF = 0.38) and 2.86 kWh/cycle (EF = 0.35), respectively, using the DOE test procedure. (5) Efficiency data are not available for compact dishwashers. AHAM data indicate that shipments of compact dishwashers are less than 2% of all dishwasher shipments in 1987. Data are not available for 220V dishwashers; however, AHAM estimates that very few were shipped in 1987.

Data submitted to the FTC were also analyzed. Appendix A.1 contains summary tables of data submitted by each manufacturer. These data were prepared by manufacturers for use in labeling of each model sold. For some models, the energy use data are separated into machine energy and water heating energy. Figure 3.1 shows the number of models with energy factors within various energy factor intervals. The main purpose of these figures is to illustrate the range of energy factors available in the marketplace in 1989. The range of energy factors for standard dishwashers is from 0.31 to 0.40 and the range of energy factors for standard water heating dishwashers is from 0.33 to 0.46. The number of shipments is not necessarily proportional to the number of models available.

Most of the differences in energy use among models are due to differences in water use. Machine electrical energy use is for electric motors and electric heaters and fans for dish drying. Not all models have fans and they consume very little energy, therefore, almost all the machine energy use is divided between motor energy to run the pump and heater energy to dry the dishes. The machine electrical consumption for a standard dishwasher is about 0.55 kWh/cycle (17.6% of total energy use) and does not vary much from model to model. Water consumption, on the other hand, varies significantly. For water-heating dishwashers, machine electrical energy use includes the electricity to heat water from 120°F to 140°F.

Reduced Water Use

The first option, reduced water use, assumes a 20% reduction in water use from the baseline of 11.9 gallons. This can be accomplished by more efficient food filters, use of alternative spray arms, or other methods. (8) FTC data (Appendix A) show a wide range of water consumption for dishwashers; there is more than a 20% decrease in water use from the highest to the lowest water consumption. An increased manufacturer cost of \$7.50 is estimated for an improved food filter.

Figure 3.1

**STANDARD DISHWASHERS
ENERGY FACTOR**

**STANDARD WATER HEATING DISHWASHERS
ENERGY FACTOR**

Improved Motor Efficiency

The improved motor efficiency option substitutes a 65% efficient motor for the baseline efficiency of 53%. This results in an energy savings of 17.8 kWh/yr. The estimated manufacturer cost increase is \$4.00.

Booster Heater and Increased Fill Control

The booster heater option can reduce energy use only because some of the incoming 120°F water is not usually boosted to 140°F. Based on test procedure, there would be no difference between a

water-heating and non water-heating dishwasher for households with an electric water heater otherwise. Households with gas-fired water heaters will have greater dishwasher energy use than households with electric water heaters when a booster heater is added to a standard dishwasher. This is because of the lower efficiency of gas relative to electric water heating. It is assumed that, for the baseline water heating dishwasher, 40% of the 120°F water (wash water only) is heated to 140°F. For the water heating dishwasher, design level 2 assumes a reduction in booster use to 20% of total incoming water. The estimated manufacturer cost to reprogram the wash and rinse cycles is \$2.00. For standard dishwashers, there are two possible branches in the cost/efficiency tables. These involve the addition of a booster heater, thermostat, and a reduction water heater setpoint temperature from 140°F to 120°F. The estimated manufacturer cost increase for this design option is \$10.00. In one branch, a booster heater is added and 40% of incoming 120°F water is heated to 140°F. It is assumed that the boosted water is used for wash cycles. In the second branch, only 20% of incoming 120°F water is heated to 140°F. The last design option, improved fill control, reduces water use by 3%. The estimated increase in manufacturer cost is \$3.00.

The energy and cost data were combined and are presented in Tables 3.3 through 3.8. In the first three tables, energy use is calculated according to the DOE test procedure; in the next three tables, usage data from a 1988/89 survey by Procter & Gamble (P&G) are used. The energy use data are disaggregated into electric motor, booster heater, dryer, and hot water energy use. Also shown is hot water use in gallons per cycle. The energy data in all of the tables are for households with electric water heaters. Households with gas-fired water heaters would consume more site energy than those with electric water heaters.

Maximum Technologically Feasible Designs

The maximum technically feasible (MTF) energy factors (according to the DOE test procedure) for standard, standard-water-heating and compact dishwashers are 0.47, 0.47, and 0.63 cycles/kWh, respectively. These energy factors correspond to 688, 688, and 510 kWh/yr of energy use, respectively.

Table 3.3 Manufacturer Cost-Energy Use Data
Standard Dishwasher, 115V
DOE Test Procedure

Level	Design Option	Cost 1988\$	Energy Factor load/kWh	Energy Use (4) kWh/year	Motor Energy kWh/cycle	Booster Energy kWh/cycle	Dryer Energy kWh/cycle	Hot Water Energy kWh/cycle	Hot Water Consumption Gal/cycle
0	Baseline	150	0.32	1006	0.30	0.00	0.25	2.58	11.9
1	Reduce Water Use	157.5	0.38	840	0.30	0.00	0.25	2.06	9.5
2	1 + Improv. Motor	161.5	0.39	823	0.24	0.00	0.25	2.06	9.5
3	2 + Booster Heater (1)	171.5	0.44	734	0.24	0.18	0.25	1.60	9.5
4	3 + Fill Control	179.5	0.45	717	0.24	0.18	0.25	1.55	9.3
5	1 + Booster Heater (2)	167.5	0.45	722	0.30	0.09	0.25	1.60	9.5
6	5 + Improv. Motor	171.5	0.46	705	0.24	0.09	0.25	1.60	9.5
7	6 + Fill Control	179.5	0.47	688	0.24	0.09	0.25	1.55	9.3

Table 3.4 Manufacturer Cost-Energy Use Data
Standard Water Heating Dishwasher, 115V
DOE Test Procedure

Level	Design Option	Cost 1988\$	Energy Factor load/kWh	Energy Use (4) kWh/year	Motor Energy kWh/cycle	Booster Energy kWh/cycle	Dryer Energy kWh/cycle	Hot Water Energy kWh/cycle	Hot Water Consumption Gal/cycle
0	Baseline	160	0.36	894	0.30	0.23	0.25	2.00	11.9
1	Reduce Water Use	167.5	0.43	751	0.30	0.18	0.25	1.60	9.5
2	1 + Booster Heater (3)	169.5	0.45	722	0.30	0.09	0.25	1.60	9.5
3	2 + Improv. Motor	173.5	0.46	705	0.24	0.09	0.25	1.60	9.5
4	3 + Fill Control	181.5	0.47	688	0.24	0.09	0.25	1.55	9.3

Table 3.5 Manufacturer Cost-Energy Use Data
Compact (Water Heating) Dishwasher, 115V
DOE Test Procedure

Level	Design Option	Cost 1988\$	Energy Factor load/kWh	Energy Use (4) kWh/year	Motor Energy kWh/cycle	Booster Energy kWh/cycle	Dryer Energy kWh/cycle	Hot Water Energy kWh/cycle	Hot Water Consumption Gal/cycle
0	Baseline	130	0.49	657	0.27	0.16	0.23	1.38	8.2
1	Reduce Water Use	137.5	0.58	558	0.27	0.13	0.23	1.11	6.6
2	1 + Booster Heater (3)	139.5	0.60	538	0.27	0.06	0.23	1.11	6.6
3	2 + Improv. Motor	143.5	0.62	522	0.22	0.06	0.23	1.11	6.6
4	3 + Fill Control	151.5	0.63	510	0.22	0.06	0.23	1.07	6.4

1. Add Booster heater and heat 40% of hot water from 120°F to 140°F
2. Add Booster heater and heat 20% of hot water from 120°F to 140°F
3. Reduce booster heater from 40% to 20% of incoming 120°F water.
4. 322 Cycles/year

Table 3.6 Manufacturer Cost-Energy Use Data
Standard Dishwasher, 115V
Procter & Gamble 1988/89 Data

Level	Design Option	Cost 1988\$	Energy Factor load/kWh	Energy Use (4) kWh/year	Motor Energy kWh/cycle	Booster Energy kWh/cycle	Dryer Energy kWh/cycle	Hot Water Energy kWh/cycle	Hot Water Consumption Gal/cycle
0	Baseline	150	0.32	716	0.30	0.00	0.25	2.58	11.9
1	Reduce Water Use	157.5	0.38	598	0.30	0.00	0.25	2.06	9.5
2	1 + Improv. Motor	161.5	0.39	585	0.24	0.00	0.25	2.06	9.5
3	2 + Booster Heater (1)	171.5	0.44	522	0.24	0.18	0.25	1.60	9.5
4	3 + Fill Control	179.5	0.45	510	0.24	0.18	0.25	1.55	9.3
5	1 + Booster Heater (2)	167.5	0.45	514	0.30	0.09	0.25	1.60	9.5
6	5 + Improv. Motor	171.5	0.46	501	0.24	0.09	0.25	1.60	9.5
7	6 + Fill Control	179.5	0.47	490	0.24	0.09	0.25	1.55	9.3

Table 3.7 Manufacturer Cost-Energy Use Data
Standard Water Heating Dishwasher, 115V
Procter & Gamble 1988/89 Data

Level	Design Option	Cost 1988\$	Energy Factor load/kWh	Energy Use (4) kWh/year	Motor Energy kWh/cycle	Booster Energy kWh/cycle	Dryer Energy kWh/cycle	Hot Water Energy kWh/cycle	Hot Water Consumption Gal/cycle
0	Baseline	160	0.36	636	0.30	0.23	0.25	2.00	11.9
1	Reduce Water Use	167.5	0.43	534	0.30	0.18	0.25	1.60	9.5
2	1 + Booster Heater (3)	169.5	0.45	514	0.30	0.09	0.25	1.60	9.5
3	2 + Improv. Motor	173.5	0.46	501	0.24	0.09	0.25	1.60	9.5
4	3 + Fill Control	181.5	0.47	490	0.24	0.09	0.25	1.55	9.3

Table 3.8 Manufacturer Cost-Energy Use Data
Compact (Water Heating) Dishwasher, 115V
Procter & Gamble 1988/89 Data

Level	Design Option	Cost 1988\$	Energy Factor load/kWh	Energy Use (4) kWh/year	Motor Energy kWh/cycle	Booster Energy kWh/cycle	Dryer Energy kWh/cycle	Hot Water Energy kWh/cycle	Hot Water Consumption Gal/cycle
0	Baseline	130	0.49	467	0.27	0.16	0.23	1.38	8.2
1	Reduce Water Use	137.5	0.58	397	0.27	0.13	0.23	1.11	6.6
2	1 + Booster Heater (3)	139.5	0.60	383	0.27	0.06	0.23	1.11	6.6
3	2 + Improv. Motor	143.5	0.62	371	0.22	0.06	0.23	1.11	6.6
4	3 + Fill Control	151.5	0.63	363	0.22	0.06	0.23	1.07	6.4

1. Add Booster heater and heat 40% of hot water from 120°F to 140°F
2. Add Booster heater and heat 20% of hot water from 120°F to 140°F
3. Reduce booster heater from 40% to 20% of incoming 120°F water.
4. 229 Cycles/year

3.3 CLOTHES WASHERS

3.3.1 Introduction

Changes to the Engineering Analysis since the July, 1989 TSD (DOE/CE-0267) include: the merging of two product classes (standard and large top-loaders) into standard top-loader, a change in the baseline model for standard top-loaders, and addition of a horizontal axis design option for standard top-loaders.

3.3.2 Product Classes

The basic models of clothes washers are segregated into classes to which different efficiency standards may apply. Three classes of clothes washers were analyzed for this TSD. They are listed in the table below. Front loaders use less water than top-loaders and thus, less energy. They also have a smaller capacity than top-loaders. Limited data indicate that front loaders (horizontal axis) are more efficient than top-loaders (vertical axis).

DOE proposed replacing the one class of top-loaders with three classes disaggregated by capacity. (9) These are compacts (1.6 ft^3 or less), standard (1.61 to 2.59 ft^3), and large capacity (2.6 ft^3 or greater). Analysis of FTC data on energy use and capacity indicated that there was no statistically significant difference in efficiencies of standard and large capacity washers. Therefore, they were combined into one class of standard washers with capacities above 1.60 ft^3 . Table 3.9 shows the list of product classes analyzed.

Table 3.9. Product Classes for Clothes Washers

1. Top-Loading, Compact
2. Top-Loading, Standard
3. Front Loading

3.3.3 Design Options

The design options analyzed are listed in Table 3.10. They are changes that can be incorporated into the design of a clothes washer to improve its efficiency. Some of the design options listed are found in existing products; others are being developed. It should be noted that the cold rinse option is found in all clothes washers currently manufactured. Therefore, it has been included in the baseline model for each clothes washer class. Two design option changes to the previous discussions (in DOE/CE-0267) are to eliminate a warm rinse and to use thermostatic mixing valves. In addition, one option has been added, the use of a horizontal axis design. All options are discussed below.

Table 3.10. Design Options For Clothes Washers

1. Eliminate Warm Rinse
2. Improve Fill Control
3. Change Configuration to Reduce Water Use
4. Reduce Thermal Mass
5. Add Insulation
6. Increase Motor Efficiency
7. Use Thermostatically Controlled Mixing Valves
8. Employ Electrolytic Dissociation of Water
9. Use Ultrasonic Vibration
10. Higher Spin Speed
11. Horizontal Axis Design

Reduction or Elimination of Warm Rinse

Almost all clothes washers have an option to use either warm or cold water for the rinse part of a cycle. Eliminating the warm rinse would save energy by reducing the amount of hot water consumed. It is generally agreed that elimination of warm rinse will not adversely affect the performance of clothes washers. Market surveys by P&G showed that consumers selected warm rinse only 26% of the time in 1988/89 compared to 48% in 1975. (10) The present test procedure for clothes washers uses 1975 data from P&G for calculation of average energy consumption. The cost/efficiency tables for clothes washers (in the Manufacturer Cost-Energy Use Data section) show energy and efficiency data for both the 1975 (DOE test procedure) and 1988/89 P&G data. The usage value for clothes washers in 1988/89 of 380 cycles/yr can be compared to the DOE test procedure value of 416 cycles/yr.

In order to estimate energy savings from elimination of warm rinse, it was assumed that there is one wash and one rinse per cycle and that a warm rinse or wash uses 50% hot and 50% cold water to obtain warm water. The 1975 and new (1988/89) P&G data are shown in Table 3.11.

Table 3.11. Procter and Gamble Temperature Selection Data

Temperature Options	1975 TUF	1988-89 TUF
Hot Wash	30%	19%
Warm Wash	55%	51%
Cold Wash	15%	30%
Warm Rinse	48%	26%

The temperature use factors (TUFs) indicate the average percentage of washes or rinses for the specified temperature selection. These TUFs are for the stock of washers existing at the time of the surveys. The stock of washers is composed of machines with five, four, and three combinations of temperature selections. There are a maximum of five selections of wash and rinse temperatures (hot/warm, warm/warm, hot/cold, warm/cold, and cold/cold) *.

* 4-setting machines have the following wash/rinse combinations: Alternative I (hot/warm, hot/cold, warm/cold, cold/cold) and Alternative III (hot/cold, warm/warm, warm/cold, cold/cold). 3-setting machines have hot/cold, warm/cold, cold/cold.

Since P&G did not provide data on the mix of these types of machines in the stock, it is not possible to create a unique set of TUFs for each type. The set of TUFs that will be presented for 1988/89 data are based on assumptions concerning the existing stock of clothes washers. These assumptions will be discussed when the details of the energy savings calculations are presented (Section 3.3.4, Manufacturer Cost and Energy Use Data).

For the purpose of performing a calculation of stock average energy savings from elimination of warm rinse, it was assumed that 15 gallons of total (hot plus cold) water is used per fill for a top-loading standard clothes washer. Two fills per cycle are assumed; one for wash and one for rinse. This is the weighted average of maximum and minimum fills and represents total water use. The weighted hot water usage is calculated from these assumptions and is shown in Table 3.12.

Table 3.12. Weighted Hot Water Usage

Temperature Options	Hot Water Use (Gallons/Cycle)	Weighted By 1975 TUF	Weighted By 1988 TUF
Hot Wash	15.0	4.50	2.85
Warm Wash	7.5	4.13	3.83
Cold Wash	0.0	0.00	0.00
Warm Rinse	7.5	3.60	1.95
Total		12.23	8.63

For 1975 P&G data, the percentage water heating energy savings from elimination of warm rinse is 3.60/12.23 or 29.4%. For 1988-89 P&G data, the percentage water heating energy savings from elimination of warm rinse is 1.95/8.63 or 22.6%. These percentage savings are independent of fill volume and are averages for the stock existing in 1975 and 1988/89, respectively. For a particular 5 or 4-setting machine, the percentage savings will be different than the above, as will be shown below. A set of new TUFs applicable to 3-setting machines are shown in Table 3.13.

Table 3.13. Temperature Use Factors for Warm Rinse Elimination

Temperature Selection	1975 Values	1988/89 Values
Hot/Cold	0.30	0.19
Warm/Cold	0.55	0.51
Cold/Cold	0.15	0.30

Improve Fill Control

Most clothes washers have an optional fill control volume which allows the user a choice of water volumes for varying loads of clothes. The amount of water needed to wash a load of clothes depends upon the amount and type of clothes and on the kind of dirt on the clothes. If an automatic control device could adjust the water level according to these factors, hot water use could be minimized. Some problems with carrying out this design option are the sensor's inability to recognize all soil types, and material build-up on sensors from water and detergent residues, which would impede the sensor's performance.

A simple manual control consists of adding markings on the tub to correlate clothes level with the fill control setting, allowing the user to more accurately use the fill control feature. This option will be low cost, but field data on consumer behavior would be necessary to evaluate the potential savings, if any.

Electronic controls may also be used to reduce water use and electric motor energy use. Limiting the number of rinse cycles would reduce water use and electricity consumption. Electronic controls can be used with detectors that optically determine the transmittance of the rinsing water and so determine the need for additional rinsing. This allows a reduction in the number of rinse cycles. (11) A microprocessor is used to manage information coming from electronic and optical sensors. This microprocessor determines the appropriate amount of water and number of rinse cycles to minimize water and energy use. The consumer has to specify the type of laundry and its degree of dirtiness. The same microprocessor can minimize electric power consumption during the mechanical action of the washing process. With input from a load detector, the microprocessor computes the minimum agitation time of the washing machine in proportion to the amount of clothing to be washed. During laboratory tests, this control device, combined with load and optical detectors, reduced energy use by as much as 20% for both electric power and water consumption as well as reducing rinse time by about 30%. The energy savings are dependent upon assumptions concerning typical wash loads and frequency of use of warm water in the rinse cycle. This information and cost data were not supplied in the above report.

Additional control devices are under development. (12) One example is a washing detector that detects the stage of washing by measuring the transmittance of the water using a similar optical method to that used by the rinse detector. Dissolved soils affect the turbidity of the washing water and thus, its transmittance. Information on the effectiveness of such controls is not yet available.

Change Configuration To Reduce Water Use

Any change in geometry that could reduce water usage will decrease hot water consumption and thus, energy use. An example of such a change would be a reduction in the space between the clothes tub and the outer tub. Manufacturers state that the clearance between the tubs is as small as they can make it, and that the space allows tub deflection when the inner tub is spinning with an off balance load. If the outer and inner tubs could be combined into one tub, this would allow the space between the tubs to be reduced to the minimum needed for water removal instead of being set by the need for wobble space. At the present time, water use data that relate to a change in configuration to decrease water use have not been identified.

Reduce Thermal Mass

The reduction of the mass of the tub and the use of a material with a lower specific heat will reduce the amount of heat transferred from the hot water to the tub. Tests by manufacturers indicate that very little energy can be saved this way because the bulk of the thermal mass is contained in the hot water. One manufacturer compared the use of porcelain enameled steel and polypropylene for the outer tub. Both machines were filled with 16 gallons of 140°F water and agitated for ten minutes. After ten minutes, there was no significant difference in water temperature between the two machines. Calculations show that if there were no heat losses through the outer tub, the equilibrium temperature for the situation described above with a steel tub would be 138.9°F. Therefore, there is little to gain by decreasing the thermal mass of the outer tub. Energy savings estimates range from 0 to 1.0%. An estimate of 0.5% is used in the cost-efficiency analysis.

Add Insulation

Some heat energy is lost through the shell of the clothes washer. If this heat loss were reduced by adding insulation around the outer tub, the water temperature associated with a hot wash could be slightly reduced. However, the wash cycle is short, the thermal mass of the water is very high, and the temperature of the tub is not very high, so there is very little change in water temperature from adding insulation. Computer simulations performed for a 20 minute wash cycle at 140°F showed that adding one inch of fiberglass insulation relative to no insulation resulted in only a 1 to 2°F increase in water temperature during parts of the wash. (13)

Increase Motor Efficiency

About 10% of the total electrical energy consumed by a typical clothes washer is used by the electric motor. The usual motor in a washing machine is a 1/2-2/3 horsepower split-phase motor with an efficiency of 65%. Replacement with a capacitor type motor would increase the motor efficiency to about 75%. This change would result in a decrease of 14 kWh/yr in energy use.

Use of Thermostatically-Controlled Mixing Valves

The warm water used in a washer is typically produced by mixing a fixed fraction of hot and cold inlet water. There are several types of systems available that provide a controlled water temperature. An older system uses a three-coil valve with the third coil producing a preset temperature. Some newer systems use thermostatically-controlled mixing valves (TMV) that cycle the hot and cold valves to arrive at a particular warm wash temperature.

An approach for saving energy with a TMV would be to reduce the hot wash temperature. For the 1975 data scenario, it is assumed that the TMV is used to lower the wash temperature from 140°F to 130°F. Therefore, the thermostatically controlled mixing valves will adjust the wash temperature for a hot wash to 130°F by mixing unequal amounts of hot and cold water. Using DOE test procedure values (cold water temperature of 60°F and 30% of washes are hot), the energy use reduction is almost 3.8% ($0.30(140-130)/(140-60)$) of the baseline water heating energy used for washing. Using 1988/89 Procter and Gamble data, the energy use reduction is only 0.7% ($0.19(132.5-130)/(132.5-60)$).

Electrolytic Dissociation of Water

The goal of electrolytic dissociation of water is to reduce hot water usage by substituting the electrolytic production of bleaching agents for the warming process. A prototype clothes washer with electrolytic dissociation of water has been successfully tested. (14) Commercial detergents perform better at high temperatures; however, the same hypochlorite concentration obtained by adding bleaching agents to water can be achieved at low temperatures if the agents are produced inside the machine. The bleaching action is due to the chemical reaction of the oxygen (derived from the chemical decomposition of the hypochlorite) with the insoluble organic compounds that constitute the dirt. Together they make soluble compounds that are dissolved in the water.

Electrolytic dissociation was tested in a laboratory electrochemical cell. Medium dirty clothes and white materials were used in the test. The washing cycle was performed in two steps. The first was with electrolytic action, which results from adding 4 gm/liter of salt at room temperature. The second stage was with a commercial detergent at a temperature of 95 to 113°F. The usual rinses, spinning, and final drainage followed. Initial tests showed that energy use dropped from about 2.65 kWh/cycle for a typical washing machine to 1.35 kWh/cycle for the new electrochemical method. The costs of such a system or for a prototypical washing machine model are not available.

Manufacturers do not feel that electrolytic dissociation is a workable approach. Primary concerns are negative effects on garments resulting from the bleaching process and poor consumer acceptance due to their inability to control the chemistry and temperature in the wash part of the cycle.

Ultrasonic Vibration

The addition of mechanical energy can reduce the need for hot water (or chemical energy) in the cleaning action of clothes washers. One potential method of delivering the mechanical energy is through ultrasonic vibrations that loosen and remove some of the dirt on the soiled clothes. Such washing machines have been produced by a Japanese firm and were to be marketed in the U.S. One U.S. manufacturer of clothes washers investigated the Japanese product and found that it did not clean clothes. They said that the Japanese company is an excellent manufacturer of ultrasonic transducers, but does not have experience with clothes washing. Extensive attempts to obtain data on such a device have proved futile.

One of the problems with ultrasonic vibration is that clothes are not uniformly exposed to the transducers, which means that some areas remain soiled. Additionally, the wash solution and the submerged clothes appear to dissipate much of the energy without being cleaned. Although ultrasonic vibration may be technically feasible, a design producing adequate cleaning action does not appear to have been developed.

Higher Spin Speed

Higher drum spin speed for clothes washers decreases the water content of the load at the end of the cycle; this lowers clothes dryer energy use for that same load. Since the current test procedure does not provide for this design, it cannot be included in the standards analysis. Although higher spin speed will not increase the energy efficiency of a clothes washer under the present test procedure, it is described here because of its great potential for reducing energy use of a combined clothes washer and clothes dryer cycle.

A method to achieve energy savings during a complete laundry cycle (washer and dryer) is to improve water extraction with a higher spin speed during the washing cycle. Water extraction by mechanical energy in a clothes washer is more efficient than by thermal energy in a clothes dryer. A National Institute of Science and Technology (NIST) study shows that to reduce moisture retention of a typical laundry load from 70% to 40%, an appropriate washer spin cycle is approximately 70 times more energy-efficient than a dryer thermal cycle. (15) Average water removal efficiency of a typical standard electric clothes dryer is approximately 2.0 lb. water/kWh. This ratio is about 134 lb. water/kWh for a clothes washer cycle with a spin speed of 525 rpm. Other researchers also find a water extraction ratio of 2.0 lb. water/kWh for an electric dryer. (16) The same researchers describe a spin dryer at 1400 rpm that removes 88 lb. water/kWh. This spin dryer has a diameter about half of a typical German clothes washer.

It is clear that higher spin speed will improve water extraction efficiency. A longer spin cycle and use of the warm rinse option of the clothes washer also improves the efficiency of water extraction. A remaining moisture level of 40% seems to be a reasonable goal to reach after the spin cycle. Increasing spin speed from 500 to 850 rpm can produce such a performance without vibration or major redesign (NIST Study). Wrinkles may appear with higher spin speed. For this reason, some European manufacturers have developed an elaborate rinse and spin cycle process for their front-loading washing machines. First, after the washing cycle, the load is rinsed between 300 and 450 rpm. In a second step, the load is spun slowly (50 rpm) in both directions in order to reposition the clothes. Then a second rinse is performed but now at a very high speed, varying between 600 rpm and 1000 rpm to extract most of remaining water. Finally a low speed spin is made to ventilate the clothes. This process reduces the problem of wrinkling. (17)

Horizontal Axis Design

One U.S. manufacturer produces clothes washers with a horizontal axis drum. Their design is incorporated in a front loader cabinet. A number of European manufacturers produce horizontal axis machines in both front and top-loading models. The horizontal axis machines rotate the drum and clothes about a horizontal axis. With this design, the drum does not have to be filled with water to the top of the clothes. Therefore, the horizontal axis machines use much less water than the vertical axis machines. Washing performance appears to be equal to that of vertical axis machines. (18)

3.3.4 Manufacturer Cost and Energy Use Data

In this section, manufacturer cost and energy consumption data are presented for two clothes washer product classes. The manufacturer cost is the cost to the manufacturer of making products with the design options shown, and does not include any markups to wholesalers or retailers. The energy use data are annual unit energy consumption in kWh for households with electric water heaters. Energy factors and energy use are calculated twice; according to the DOE test procedure and with new field usage data (P&G). Both usage and TUFs are different in the two approaches. The usage factor is 416 and 380 cycles per year for the DOE test procedure and the new P&G data, respectively. Basic physical and engineering principles and manufacturer supplied data are used to perform the energy savings calculations.

The cost data are mostly from a report prepared by ADM Associates, Inc. (19) The cost data were collected from several manufacturers of clothes washers and averaged in order to protect the confidentiality of data received from individual manufacturers. Independent estimates of

the cost of efficient electrical motors were obtained from consultants and motor manufacturers. Cost data were only received for standard-capacity clothes washers. These data were extrapolated to compact clothes washers. No cost data were received for the other classes of clothes washers; however, they account for less than 5% of all clothes washer shipments. Based on comments on the Proposed Rule, changes were made in cost estimates for elimination of warm rinse and improved motor efficiency. Appendix A.4 contains disaggregated costs for each product class. Total costs are divided among labor, material, purchased parts, tooling and capital costs, and shipping and packaging.

Energy Use Data

Energy consumption data were obtained from several sources. AHAM provided energy use data for several typical compact and standard capacity top-loading clothes washers. Data submitted to the FTC for 1989 models were also analyzed. Appendix A.3 contains summary tables of data submitted by each manufacturer to the FTC. These data were prepared by manufacturers for labeling of each model sold. For some models the energy consumption was separated into machine energy and water heating energy. Figure 3.2 shows the number of models with energy factors within various energy factor intervals. The main use of these figures is to show the range of energy factor values among all models sold by manufacturers in 1989. The number of models is not necessarily proportional to the number of shipments. In Figure 3.3, we have also plotted the EF of each model for which we could obtain data as a function of capacity. The number of temperature selections is also indicated. These data were used to establish new baselines for compact and standard clothes washers. Since the 5-setting machines had the lowest energy factors, the baseline was chosen to be a model with 5 temperature selection choices. Based on comments on the Proposed Rule, the baseline models were changed and the energy use calculations for the addition of thermostatically controlled mixing valves and elimination of warm rinse were modified. As mentioned earlier, horizontal axis design washers were also added to the design options considered.

For the standard and compact clothes washers, the baselines have energy factors of 0.86 and 0.76 ft³/kWh, respectively, according to the DOE test procedure. The two baseline units have five combinations of wash and rinse temperatures. The settings are hot/warm, warm/warm, hot/cold, warm/cold, and cold/cold. The energy use is the sum of the motor and hot water energy consumptions. The motor is assumed to have an efficiency of 65% for both product classes. Motor energy use is 0.27 and 0.25 kWh/cycle respectively, for standard and compact units. The water consumption is computed assuming that, during a normal cycle, a clothes washer uses two fills of water of equal volume, one for the wash and the other for the rinse. An additional 2 and 1.5 gallons of cold water is used during the spray rinse for standard and compact units, respectively.

The analysis is done in two parts: the first by using the DOE test procedure and the second using the 1988/89 P&G data. Data from Table 3.11 were used to generate TUFs for five, four, and three-setting machines. The TUFs that are generated are not unique because the new P&G data are for the stock of machines present in 1988/89 and assumptions had to be made about the market shares of the different settings; these were 50, 30, 20, and 10% for 5, 4 (alternative I), 4 (alternative III), and 3-settings, respectively. The TUF Tables 3.14 and 3.15 are shown below as they appear in the test procedure and for the new 1988/89 data. Alternatives I and III are defined in the DOE test procedure for clothes washers, and above in Section 3.3.

Figure 3.2

Figure 3.3

Eliminate Warm Rinse

The first design option is to eliminate the warm/warm setting. The five-setting machine becomes a 4-setting, alternative I machine. Energy savings were computed directly by applying the TUFs. For the baseline standard clothes washer, a total of 33.3 gallons of water per cycle are used, two gallons of which are cold water for the spray rinse. Thus, 15.65 gallons of water are used in both the wash and rinse portions of the cycle. The hot water reduction resulting from elimination of the warm/warm setting is 2.35 gallons. This yields an energy savings of 0.50 kWh/cycle, or 211 kWh/yr. The second design option is to eliminate warm rinse. This results in a 3-setting machine. The energy savings were computed from the TUFs. The total energy savings (5-setting to 3-setting machine) are 338 kWh/yr or 27% of the baseline energy use. The estimated manufacturer cost to alter the temperature selections is \$1.00 per unit.

Horizontal Axis Design

The next option, horizontal axis design, incorporates a drum that rotates about a horizontal rather than a vertical axis. The machine is still top-loading in design. Hot water use is decreased by 64% and total water consumption by 31%. (20) The estimated cost of retooling to manufacture horizontal axis top-loading clothes washers is \$110.

Thermostatic Mixing Valves, Plastic Tub, and Improved Motor Efficiency

Three other design options were analyzed: thermostatic mixing valves, plastic tubs, and improved motor efficiency. For the DOE test procedure, about 3.8% of hot water energy use for washing is saved by incorporation of thermostatically controlled mixing valves. For the 1988/89 P&G data, only 0.7% of the hot water energy use for washing is saved. The estimated manufacturer cost for this design option is \$13. Plastic tubs are estimated to save about 0.5% of the total energy consumption at an estimated manufacturer cost of six dollars. For the improved motor efficiency option a 65% efficient motor is replaced by a 75% efficient motor. The energy savings are approximately 0.036 kWh/cycle for the standard clothes washer. The estimated manufacturer cost for the more efficient motor is \$7.50.

The energy and cost data were combined and are presented in Tables 3.16 through 3.19. The first two tables show energy use data calculated using the DOE test procedure; the next two tables use data on usage and TUFs from the Procter and Gamble 1988/89 survey. Energy use is disaggregated into motor and hot water energy consumption. Both hot water energy use and total gallons of water are also tabulated.

Maximum Technologically Feasible Designs

The maximum technically feasible (MTF) energy factor, according to the DOE test procedure, for both compact and standard clothes washers is 3.19 ft³/kWh. This corresponds to 189 and 339 kWh/yr of energy consumption for compact and standard clothes washers, respectively.

Table 3.14. DOE Test Procedure TUFs

Number of Settings Wash/Rinse Selections	5	4 - Alt I	4 - Alt III	3
Hot/Warm	0.18	0.18	0.00	0.00
Hot/Cold	0.12	0.12	0.12	0.30
Warm/Warm	0.30	0.00	0.18	0.00
Warm/Cold	0.25	0.55	0.55	0.55
Cold/Cold	0.15	0.15	0.15	0.15

Table 3.15. 1988 LBL-Procter & Gamble TUFs

Number of Settings Wash/Rinse Selections	5	4 - Alt I	4 - Alt III	3
Hot/Warm	0.11	0.11	0.00	0.00
Hot/Cold	0.08	0.08	0.19	0.19
Warm/Warm	0.32	0.00	0.11	0.00
Warm/Cold	0.19	0.51	0.40	0.51
Cold/Cold	0.30	0.30	0.30	0.30

3.4 CLOTHES DRYERS

3.4.1 Introduction

Changes to the Engineering Analysis since the July, 1989 TSD (DOE/EA-0267) include the addition of two design options (microwave and heat pump dryers) to the manufacturer cost/efficiency tables.

3.4.2 Product Classes

Four classes of clothes dryers were analyzed. These product classes are distinguished by different energy sources and by performance-related features. Gas and electricity are the energy sources. The performance related features include drum capacity and input voltage. Table 3.20 shows the list of product classes.

Table 3.20. Product Classes For Clothes Dryers

1. Electric, Standard
2. Electric, Compact 120V
3. Electric, Compact 240V
4. Gas, Standard

Table 3.16 Manufacturer Cost-Energy Use Data
Clothes Washer, Top-Loading, Compact Capacity*
DOE Test Procedure

Level	Design Option	Cost 1988\$/unit	Energy Factor ft ³ /kWh	Energy Use** kWh/yr	Motor Energy kWh/cycle	Hot Water Energy kWh/cycle	Hot Water Consum. Gal/cycle	Total Water Consum. Gal/cycle
0	Baseline 5 Settings	155.0	0.67	906	0.25	1.93	8.9	23.4
1	Eliminate Warm/Warm Set.	155.5	0.79	758	0.25	1.57	7.3	23.4
2	Eliminate Warm Rinse	156.0	0.90	670	0.25	1.36	6.3	23.4
3	2 + Improv. Motor	163.5	0.92	656	0.22	1.36	6.3	23.4
4	3 + Therm. Mix. Valve	176.5	0.95	635	0.22	1.31	6.1	23.4
5	4 + Plastic Tub	182.5	0.96	631	0.22	1.30	6.0	23.4
6	2 + Horizontal Axis	266.0	3.07	196	0.08	0.39	1.8	12.7
7	6 + Therm. Mix. Valve	279.0	3.17	190	0.08	0.37	1.7	12.7
8	7 + Plastic Tub	285.0	3.19	189	0.08	0.37	1.7	12.7

* Capacity equals 1.45 ft³.

Table 3.17 Manufacturer Cost-Energy Use Data
Clothes Washer, Top-Loading, Standard Capacity*
DOE Test Procedure

Level	Design Option	Cost 1988\$/unit	Energy Factor ft ³ /kWh	Energy Use** kWh/yr	Motor Energy kWh/cycle	Hot Water Energy kWh/cycle	Hot Water Consum. Gal/cycle	Total Water Consum. Gal/cycle
0	Baseline 5 Settings	200.0	0.86	1258	0.27	2.75	12.8	33.3
1	Eliminate Warm/Warm Set.	200.5	1.03	1047	0.27	2.25	10.4	33.3
2	Eliminate Warm Rinse	201.0	1.18	920	0.27	1.94	9.0	33.3
3	2 + Improv. Motor	208.5	1.19	905	0.23	1.94	9.0	33.3
4	3 + Therm. Mix. Valve	221.5	1.24	875	0.23	1.87	8.7	33.3
5	4 + Plastic Tub	227.5	1.24	871	0.23	1.86	8.6	33.3
6	2 + Horizontal Axis	311.0	3.07	352	0.15	0.70	3.2	22.8
7	6 + Therm. Mix. Valve (1)	324.0	3.17	341	0.15	0.67	3.1	22.8
8	7 + Plastic Tub	330.0	3.19	339	0.15	0.67	3.1	22.8

* Capacity equals 2.60 ft³.

** 416 Cycles/year

Table 3.18 Manufacturer Cost-Energy Use Data
Clothes Washer, Top-Loading, Compact Capacity*
Procter & Gamble 1988/89 Data

Level	Design Option	Cost 1988\$/unit	Energy Factor ft ³ /kWh	Energy Use** kWh/yr	Motor Energy kWh/cycle	Hot Water Energy kWh/cycle	Hot Water Consum. Gal/cycle	Total Water Consum. Gal/cycle
0	Baseline 5 Settings	155.0	0.80	688	0.25	1.56	7.2	23.4
1	Eliminate Warm/Warm Set.	155.5	1.01	546	0.25	1.19	5.5	23.4
2	Eliminate Warm Rinse	156.0	1.11	495	0.25	1.05	4.9	23.4
3	2 + Improv. Motor	163.5	1.14	482	0.22	1.05	4.9	23.4
4	3 + Plastic Tub	169.5	1.15	480	0.22	1.05	4.9	23.4
5	4 + Therm. Mix. Valve	182.5	1.16	477	0.22	1.04	4.8	23.4
6	2 + Horizontal Axis	266.0	3.77	146	0.08	0.30	1.4	12.7
7	6 + Plastic Tub	272.0	3.79	145	0.08	0.30	1.4	12.7
8	7 + Therm. Mix. Valve	285.0	3.81	145	0.08	0.30	1.4	12.7

* Capacity equals 1.45 ft³.

Table 3.19 Manufacturer Cost-Energy Use Data
Clothes Washer, Top-Loading, Standard Capacity*
Procter & Gamble 1988/89 Data

Level	Design Option	Cost 1988\$/unit	Energy Factor ft ³ /kWh	Energy Use** kWh/yr	Motor Energy kWh/cycle	Hot Water Energy kWh/cycle	Hot Water Consum. Gal/cycle	Total Water Consum. Gal/cycle
0	Baseline 5 Settings	200.0	1.04	950	0.27	2.23	10.3	33.3
1	Eliminate Warm/Warm Set.	200.5	1.32	746	0.27	1.70	7.9	33.3
2	Eliminate Warm Rinse	201.0	1.47	674	0.27	1.50	7.0	33.3
3	2 + Improv. Motor	208.5	1.50	660	0.23	1.50	7.0	33.3
4	3 + Plastic Tub	214.5	1.50	657	0.23	1.50	6.9	33.3
5	4 + Therm. Mix. Valve	227.5	1.51	653	0.23	1.49	6.9	33.3
6	2 + Horizontal Axis	311.0	3.77	262	0.15	0.54	2.5	22.8
7	6 + Plastic Tub	317.0	3.79	260	0.15	0.54	2.5	22.8
8	7 + Therm. Mix. Valve	330.0	3.81	259	0.15	0.53	2.5	22.8

* Capacity equals 2.60 ft³.

** 380 Cycles/year

3.4.3 Design Options

The design options analyzed are listed in Table 3.21. They are changes that can be incorporated into the design of a clothes dryer to improve its efficiency. Some of the design options are already found in existing products; others are being developed. It should be noted that gas dryers no longer may use standing pilot lights; therefore, electronic ignition has been included in the baseline gas clothes dryer. Both electric and gas baseline dryers are assumed to use time termination rather than temperature or humidity control.

Table 3.21. Design Options For Clothes Dryers

-
1. Automatic Termination by Temperature Sensing
 2. Automatic Termination by Moisture Sensing
 3. Insulation
 4. Recycle Exhaust Heat
 5. Inlet Air Preheat
 6. Inlet Air Preheat, In Condensing Mode
 7. Modified Operating Conditions
 8. Heat Pump
 9. Microwave Dryer
-

Automatic Termination by Temperature and Moisture Sensing

The baseline dryer is assumed to use timed drying cycles. After a time interval that is consumer specified, the dryer automatically turns off. With automatic termination by temperature sensing, an exhaust air temperature sensor controls the length of the drying cycle. With automatic termination by moisture sensing, the moisture content of the clothes in the dryer is checked by sensors that measure conductivity. A timer runs when the sensors are not in contact with damp clothes. After a pre-specified (by manufacturer) time period, the cycle terminates.

The test procedure for dryers allows an energy credit of 12% for either temperature or moisture sensing relative to time control to terminate drying. There has been some controversy as to whether the use of moisture sensors reduces energy consumption relative to temperature sensors. Based on field measurements conducted by one manufacturer, it appears that the test procedure credits are appropriate. (21) The estimated manufacturer cost for this design option is eight dollars.

Insulation

During the drying cycle some parts of the dryer are warmer than the ambient air. Insulating the dryer drum would reduce the heat lost through conduction, convection, and radiation to the surrounding air. Two dryer manufacturers report an energy savings of about 2% from the addition of one inch of fiberglass insulation around the dryer drum. Computer simulations performed by other researchers with a thermal model indicated a 6% energy savings. (22)

Manufacturers are concerned that the insulation would eventually degrade, resulting in fiberglass particles being drawn into the drum and onto the clothes. (Dryer air circulation systems operate with a negative air pressure in the drum relative to the outside). These particles can cause skin irritation for some people.

Potential substitutes for fiberglass are polystyrene or polyurethane foam insulation. They have similar or lower thermal conductivities and do not cause skin irritation. The estimated energy savings used in the cost/energy use analysis is 2% and the associated manufacturer cost is \$6.60.

Methods of Exhaust Heat Recovery

The next three design options have in common the objective of recovering heat energy in the exhaust air stream. It is estimated that about 20 to 25% of total heat input energy is lost through the dryer vent. Therefore, when total energy use (including electric motor) is considered, the theoretical maximum energy savings from recovering all of the exhaust heat would be about 18 to 20%. This heat energy can be partially recovered by directly reintroducing the exhaust air at the inlet

or by transferring heat energy from the exhaust air stream to another air stream via a heat exchanger. The advantage of the former method is that it is less costly and the advantage of the latter method is that moisture is not reintroduced to the dryer. If condensation of water vapor takes place in the heat exchanger, then that design option will be called inlet air preheat in the condensing mode.

Recycle Exhaust Heat

In this design option, a portion of the exhaust air stream is reintroduced at the dryer air inlet. This recovers a portion of the energy in the exhaust air stream and reduces the energy needed to raise the inlet air to drying temperatures. The exhaust air suitable for direct recovery would be available only late in the drying cycle when most of the moisture is evaporated and the air temperature rises. Therefore, the realizable energy savings are significantly less than the theoretical maximum of about 20%. The estimated energy use reduction for this option is 6% and the associated manufacturer cost is \$30.

Exhaust air can be recycled late in the dryer cycle with available technology, using extra duct work and mechanical air diverters. Recycling presents several technical problems. There is the potential for lint accumulation in the duct work and on the clothes. Recycling of exhaust air could present a potential fire hazard since some large pieces of lint could enter the heater area. For a gas dryer, there is also a potential inability to promote satisfactory combustion.

Experiments performed with a 230V electric dryer (baseline energy use above 3.0 kWh/cycle) showed that energy savings ranged from 10 to 18% depending on the fraction of exhaust air recirculated. (23) A fine nylon-mesh filter was installed to minimize the amount of recirculated lint. These energy savings are greater than one would expect because of the large quantity of moisture in the exhaust early in the cycle. NIST testing indicated savings ranging from three to six percent for this design option. (24)

Inlet Air Preheat

With this design option, a heat exchanger is used to recover exhaust heat energy and to preheat inlet air. This system should be feasible for both gas and electric dryers since none of the exhaust air reenters the dryer. Energy savings are achieved either by a faster drying time or by reducing heater input power. A number of researchers have investigated this design option for clothes dryers. One manufacturer has estimated 2-3% energy savings, and NIST has estimated 3-6% energy savings. (25) Both of the above experiments were carried out in the non-condensing mode. That is, moisture in the exhaust air was not condensed, which limited the maximum heat recovery.

Problems with this design are that a large surface is required to achieve sufficient heat transfer and that lint may accumulate on the heat transfer surfaces. Although every dryer is equipped with a lint filter, considerable lint is still contained in the exhaust air. This lint can foul the heat exchanger, decreasing its effectiveness. Additionally, to overcome the increased resistance to air flow, an additional blower is needed at the fresh air inlet or a stronger blower in the exhaust air duct is required.

Inlet Air Preheat, in Condensing Mode

Dryers that utilize a condenser to capture some of the sensible and latent heat in the exhaust air stream have been manufactured both in the U.S. and Europe. In this design option, a heat exchanger is used to transfer heat energy from the exiting air to the cooler incoming air. If the effectiveness of the heat exchanger is high enough, the water vapor in the exhaust air will condense. Therefore, more heat energy is transferred than in a sensible heat exchanger system as described above. In Europe, condenser dryers have been used in an open system to supply space heat during the winter. In the U.S., they have been used to avoid the need for vents in apartments. Energy savings data are not available for a closed system condenser dryer. Therefore, although a higher energy savings are expected than for inlet air preheat with a sensible heat exchanger, the energy savings cannot be quantified at this time.

Manufacturers have identified several problems with this design option: a drain for the moisture is required; lint accumulation on the heat exchanger reduces the heat transfer efficiency; and lint can accumulate and clog the drain. The manufacturer cost for this design option will be greater than for the previous one because installation of a drain is required and humid operating conditions require extensive use of stainless steel or glass in the heat exchanger to avoid corrosion. Also, use of recycled humid air could extend drying time.

Modified Operating Conditions

Reducing air flow and/or heat input rate changes the efficiency of the drying process. Manufacturers have currently selected operating points which match the dryer cycle time to the washer cycle time. This is not necessarily the optimum dryer operation from an efficiency standpoint. Tests with reduced air flow rates have shown energy savings of as much as 8%, but the drying time increased from about 40 to 55 minutes. (26) Tests by the same researchers with reduced heater input (3.1 kW instead of 3.45 kW) yielded no energy savings and increased the drying time from 40 to 56 minutes. For a very low heater input (1.25 kW), energy savings of around 5% were achieved, but the drying times were very long (112 minutes).

Heat Pump Dryer

Another way to recover exhaust heat energy is to recirculate all the exhaust air back to the dryer while moisture is removed by a refrigeration-dehumidification system. No heating element is needed. The exhaust air of the dryer enters the evaporation coil of the dehumidifier where it cools down below the dew point, and sensible and latent heat are extracted. The heat is transferred to the condenser coil by the refrigerant and reabsorbed by the air, which is moving in a closed air cycle. A heat pump dryer is essentially a dryer and an air conditioner packaged as one appliance. A drain is required to remove the condensate; however, one is usually available since clothes washers and dryers are usually located side by side.

A heat pump dryer has been developed by a U.S. company which has successfully tested several prototypes and found energy savings of 68% compared to energy use by a conventional electric clothes dryer. The estimated retail cost is approximately twice that of a conventional electric dryer. The refrigeration system COP is approximately 2.6. Drying times were essentially the same as for the conventional dryer. No vent is required because the air moves in a closed system. The dryer operates on a standard 120V circuit. The prototype uses a disposable filter to reduce lint in the air system. One inch of polyisocyanurate insulation was used to avoid condensation of water vapor in the recirculated air.

The prototypes were constructed by modifying a conventional electric dryer. The unit looks like a conventional dryer except that it contains the refrigeration system in the rear of the cabinet where the heater usually goes. The extension on the back of the dryer is estimated to be about the same depth as a vent duct, so the cabinet may fit in the same space as a conventional dryer.

More maintenance will probably be required for the heat pump dryer than for a conventional dryer. The heater will be replaced by equipment found in a small room air conditioner: a condenser, evaporator, compressor, expansion valve, etc. On the other hand, installation costs may be less than for a conventional electric dryer because the heat pump dryer does not need an exhaust vent as does a conventional dryer.

Microwave Dryer

Microwaves can be absorbed by water, thereby heating the water enough to cause evaporation. This would be a direct and efficient manner to remove moisture from clothes. Prototype microwave dryers have been built and tested. Manufacturers have attempted to perfect this technology. Clothes with metallic threads may be damaged by the present prototypes. Uniform drying is also a problem since the microwaves may not reach the interior of the clothing container.

3.4.4 Manufacturer Cost and Energy Use Data

In this section, manufacturer cost and energy consumption data are presented for four product classes. The manufacturer cost is the cost to the manufacturer of producing products with the design options shown, and does not include any markups to wholesalers or retailers. The energy use data are kWh/yr for electric dryers and millions of Btu/yr for gas dryers. Energy use is calculated according to the DOE test procedure. The capacity of the baseline standard dryers is 5.9 ft³ and they are assumed to use time termination. The capacity of compact dryers is 3.45 ft³ and they are also assumed to use time termination. Basic physical and engineering principles and some manufacturer supplied data were used to perform the energy savings calculations.

The cost data are mostly obtained from a report by ADM Associates, Inc. (28) Two exceptions are for microwave and heat pump dryers. For these two designs, cost estimates were provided by others and then reviewed (details below). The data for the other design options were obtained from several dryer manufacturers and averaged in order to protect the confidentiality of data received from individual manufacturers. Data were received only for standard-capacity dryers. These data were extrapolated for compact dryers. Less than 5% of dryer shipments are compacts. Appendix A.5 contains disaggregated costs for each product class. Total costs are divided among labor, materials, purchased parts, tooling, capital costs, and shipping and packaging.

The energy and cost data were combined and are presented in Tables 3.22 through 3.29. Energy factors and energy use are calculated according to the DOE test procedure and using 1988/89 P&G usage data. The usage factors are 416 and 359 cycles/yr for the DOE test procedure and for the 1988/89 Procter and Gamble survey, respectively.

Energy Use Data

Energy consumption data are not regularly collected by either AHAM or the FTC. For the original analysis, the only energy consumption data available were those received from the manufacturers. These data were limited to the typical electric and gas standard dryers for which manufacturer cost data were received. During the public comment period, AHAM provided data on sales weighted energy factors (SWEFs) for clothes dryers shipped during 1988. These SWEFs are 2.76, 2.82, and 2.46 lbs/kWh for electric standard, electric compact (120V), and gas standard dryers, respectively.

Automatic Termination and Insulation

For automatic termination of the drying cycle, we are using the DOE field use factors to estimate an energy savings of 12% for termination with either a moisture or temperature sensor relative to time termination. The manufacturer cost of eight dollars is equal to that of replacing time termination with termination by temperature control. For the addition of one inch of insulation, the energy savings (2%) and manufacturer cost are unchanged from the previous analysis.

Recycle Exhaust Heat

For the recycle exhaust heat option, we are retaining the previous energy savings estimate (6%) and manufacturer cost (\$30). This reduction in energy use is for recycling sensible heat energy that would otherwise be exhausted to the outside. We estimated that about 20-25% of the sensible heat energy is lost as sensible heat in the exhaust. Much of this heat energy cannot be recovered because the use of moist air at the beginning part of the cycle will lengthen the drying time and would not save much energy.

Heat Pump Dryer

Relative to a conventional dryer, the energy savings of 65% for a heat pump dryer are obtained from the prototype results. The incremental manufacturer cost is estimated to be \$150. It was obtained in three ways. One estimate came from Nyle Corporation. (27) They predicted a doubling of the price over a conventional dryer. Two other estimates come from consideration of the cost of a small (8,000 Btu/hr) room air conditioner. The heat pump dryer is essentially a conventional dryer plus a small room air conditioner operating in the dehumidification mode. A previous analysis found a \$145 baseline cost for an 8,000 Btu/hr room air conditioner. (29)

Table 3.22 Manufacturer Cost-Energy Use Data
Standard Electric Dryer *
DOE Test Procedure

Level	Design Option	Cost 1988\$/unit	Energy Factor lb/kWh	Energy Use kWh/yr **
0	Baseline	150.0	2.60	1120
1	Automatic Termination	158.0	2.95	986
2	1 +Insulation	164.6	3.01	966
3	2 +Recycle Exhaust	194.6	3.21	908
4	2 +Microwave	252.1	4.07	715
5	2 +Heat Pump	314.6	8.61	338

* Capacity equals 5.9 ft3.

Table 3.23 Manufacturer Cost-Energy Use Data
Compact Electric Dryer (120V) *
DOE Test Procedure

Level	Design Option	Cost 1988\$/unit	Energy Factor lbs/kWh	Energy Use kWh/yr **
0	Baseline	125.0	2.70	462
1	Automatic Termination	133.0	3.07	407
2	1 +Insulation	139.6	3.13	399
3	2 +Recycle Exhaust	169.6	3.33	375
4	2 +Microwave	227.1	4.23	295
5	2 +Heat Pump	289.6	8.95	140

* Capacity equals 3.45 ft3.

Table 3.24 Manufacturer Cost-Energy Use Data
Compact Electric Dryer (240V) *
DOE Test Procedure

Level	Design Option	Cost 1988\$/unit	Energy Factor lbs/kWh	Energy Use kWh/yr **
0	Baseline	140.0	2.50	499
1	Automatic Termination	148.0	2.84	439
2	1 +Insulation	154.6	2.90	431
3	2 +Recycle Exhaust	184.6	3.08	405
4	2 +Microwave	242.1	3.92	319
5	2 +Heat Pump	304.6	8.28	151

* Capacity equals 3.45 ft3.

Table 3.25 Manufacturer Cost-Energy Use Data
Standard Gas Dryer *
DOE Test Procedure

Level	Design Option	Cost 1988\$/unit	Energy Factor lbs/kWh	Energy Use MBtu/yr **
0	Baseline	170.0	2.30	4.32
1	Automatic Termination	178.0	2.61	3.80
2	1 +Insulation	184.6	2.67	3.73
3	2 +Recycle Exhaust	214.6	2.84	3.50

* Capacity equals 5.9 ft3.

** 416 Cycles/year

Table 3.26 Manufacturer Cost-Energy Use Data

Standard Electric Dryer *

Procter & Gamble 1988/89 Data

Level	Design Option	Cost 1988\$/unit	Energy Factor lb/kWh	Energy Use kWh/yr**
0	Baseline	150.0	2.60	967
1	Automatic Termination	158.0	2.95	851
2	1 +Insulation	164.6	3.01	834
3	2 +Recycle Exhaust	194.6	3.21	784
4	2 +Microwave	252.1	4.07	617
5	2 +Heat Pump	314.6	8.61	292

* Capacity equals 5.9 ft3.

Table 3.27 Manufacturer Cost-Energy Use Data

Compact Electric Dryer (120V) *

Procter & Gamble 1988/89 Data

Level	Design Option	Cost 1988\$/unit	Energy Factor lbs/kWh	Energy Use kWh/yr**
0	Baseline	125.0	2.70	399
1	Automatic Termination	133.0	3.07	351
2	1 +Insulation	139.6	3.13	344
3	2 +Recycle Exhaust	169.6	3.33	323
4	2 +Microwave	227.1	4.23	255
5	2 +Heat Pump	289.6	8.95	120

* Capacity equals 3.45 ft3.

Table 3.28 Manufacturer Cost-Energy Use Data

Compact Electric Dryer (240V) *

Procter & Gamble 1988/89 Data

Level	Design Option	Cost 1988\$/unit	Energy Factor lbs/kWh	Energy Use kWh/yr**
0	Baseline	140.0	2.50	431
1	Automatic Termination	148.0	2.84	379
2	1 +Insulation	154.6	2.90	372
3	2 +Recycle Exhaust	184.6	3.08	349
4	2 +Microwave	242.1	3.92	275
5	2 +Heat Pump	304.6	8.28	130

* Capacity equals 3.45 ft3.

Table 3.29 Manufacturer Cost-Energy Use Data

Standard Gas Dryer *

Procter & Gamble 1988/89 Data

Level	Design Option	Cost 1988\$/unit	Energy Factor lbs/kWh	Energy Use MBtu/yr**
0	Baseline	170.0	2.30	3.73
1	Automatic Termination	178.0	2.61	3.28
2	1 +Insulation	184.6	2.67	3.22
3	2 +Recycle Exhaust	214.6	2.84	3.02

* Capacity equals 5.9 ft3.

** 359 Cycles/year

A third estimate of manufacturer cost comes from a retail cost of \$316 for an 8,000 Btu/hr room air conditioner corresponding to a manufacturer cost of \$158 given a manufacturer to retail markup of 2.0. An installation cost of \$60 for connection of a water drain to the condensate pan of the heat pump dryer has been added to the initial costs of purchasing a heat pump dryer. We obtained \$60 from the assumption of one hour or less of labor (at \$50 per hour) plus \$10 for parts (hose- and T-connector). It is not certain if additional exhaust air venting costs would be charged for new home construction.

For maintenance, it was assumed that there would be one service call at 5 years. The call would require \$50 for parts and \$50 for labor. With a 7% discount rate, the present value is \$71. Rounding off, the installation and maintenance add \$130 to the incremental manufacturer cost of a heat pump dryer. There are other factors to consider when establishing the incremental cost of heat pump dryers. These factors include: the money saved from the absence of an electric heating coil or a gas burner, the absence room air conditioner cabinets, and from the additional cost of connecting the air conditioner components (heat exchangers, compressor controls) to the dryer components (drum, fan, temperature, or moisture sensors). We are assuming that these costs cancel each other out.

Microwave Dryer

The energy savings from the use of a microwave dryer are estimated to be equal to 26% when compared to a conventional dryer. This estimate is from analysis of data submitted by a company developing a prototype microwave dryer. (30) According to the developers, the prototype microwave dryer employs two magnetrons and can safely dry clothes with metal zippers and buttons. Clothes with metallic threads may be damaged by the present prototype. The efficiency of the magnetrons (75%) is the best available. When placed in the configuration of the dryer, the magnetron system, which includes waveguide and cavity, efficiency drops to about 55%; this is similar to the efficiency drop experienced in a microwave oven. For the incremental cost of a microwave dryer relative to a conventional dryer, we used the midpoint of an estimate provided by two commenters on the Notice of Proposed Rulemaking. (31) The estimated retail cost ranged from \$325-\$625. We chose to use the retail cost of \$475, which resulted in a \$175 incremental consumer cost. This appears to be a reasonable estimate for the addition of two magnetrons plus electronic controls to a conventional dryer.

Maximum Technologically Feasible Designs

Using DOE test procedure usage data, the maximum technically feasible (MTF) energy factors for electric standard, compact 110V, compact 240V, and gas standard dryers are 8.61, 8.95, 8.28 and 2.84 lb/kWh, respectively. These energy factors correspond to annual energy uses of 338 kWh, 140 kWh, 151 kWh, and 3.50 million Btu, respectively.

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4. 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 prevail if standards were enacted (see Chapter 5). The difference between the two projections is defined as the incremental impact of standards.

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

4.1 ECONOMIC AND DEMOGRAPHIC DATA

The Lawrence Berkeley Laboratory Residential Energy Model (LBL-REM) is used to derive projections of residential energy demand. The model is described in Section 2.2.2 and Appendix B. 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 4.1 through 4.6. (Other economic data, such as equipment price, initial market shares, elasticities for market shares, efficiency choices, and usage behaviors are described in Appendix B.)

Table 4.1. Demographic Projections

	U.S. Population (millions)	Occupied Households: (millions)	Single family	Multi- family	Mobile Homes
1980	225.3	80.0	53.4	22.5	4.1
1985	236.5	83.5	55.7	23.5	4.4
1990	247.6	87.2	58.1	24.4	4.7
1995	257.6	90.6	60.6	25.1	5.0
2000	265.6	93.3	62.9	25.2	5.2
2005	272.6	96.2	65.5	25.3	5.4
2010	279.3	98.8	67.8	25.5	5.6
2015	285.7	101.2	69.8	25.6	5.81

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

Population Projection

The population projection is for 48 states* and is based on Bureau of Census data to the year 2000 (1). The population projections are consistent with those used by DOE in projecting energy prices. Projections for intermediate years are obtained by interpolation of growth rates for each state; projections for later years are obtained by extrapolation, assuming that the annual rate of increase in population declines after 2000, from an average of 0.71% per year from 1990 to 2000, to 0.49% per year from 2000 to 2015.

* Excluding Alaska and Hawaii.

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 4.2. Housing Starts, 1980-2015 (Thousands)

	Single-family	Multi-family	Mobile homes	Total
1980	847	433	221	1501
1985	1064	665	280	2009
1990	1149	548	242	1939
1995	1184	483	244	1911
2000	1170	520	246	1936
2005	1138	498	251	1887
2010	1084	481	255	1820
2015	1041	471	258	1770

Source: National Association of Home Builders (NAHB), 1980-1985; Data Resources Inc., Regional Information Service, Summer, 1987 (1986-2000).

Housing Starts

Single-family and multifamily. Figures for past (1980-1985) housing starts by state come from National Association of Home Builders (NAHB) data (2). 1986 housing starts by region are taken from Data Resources, Inc. (3). Projections (1987-1996 and 2000) by region come from Data Resources. Housing starts in other years (1997-1999 and 2001-2015) 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 4.3. House Retirement Rates
(Percent of Stock per Year)

Single-family	0.5
Multifamily	1.0
Mobile home	3.9

Disposable Personal Income

Disposable personal income (1980-1986) is from Survey of Current Business, converted to 1987 dollars assuming 4% inflation for 1987 and the Consumer Price Index-Urban for other years. For 1987-2000, the projection from the DOE *Annual energy outlook, 1989* is used, similarly converted to 1987 dollars. For 2001-2015, the projection is extended, assuming a linear increase in disposable personal income, with the annual increase being the average of the increases from 1980 to 2000. For use in the LBL-REM, disposable personal income is expressed per household.

Table 4.4. Disposable Personal Income (1988 Dollars)

	Total (Billions)	Per Occupied Household (Thousands)
1980	2530	31.6
1985	3008	36.0
1990	3467	39.8
1995	3844	42.4
2000	4269	45.7
2005	4695	48.8
2010	5121	51.8
2015	5547	54.8

Source: (1980-1986) Survey of current business;
(1987-2000) DOE/EIA *Annual energy outlook*, 1989

Table 4.5. Residential Energy Prices
(1988 Dollars per Million Btu)

	Electricity*	Natural Gas	Distillate Oil	LPG
Past				
1980	22.75	5.20	10.13	11.44
1985	23.21	6.59	8.39	8.49
1986	22.04	6.03	4.83	4.93
Projected				
1987	22.40	5.57	5.97	8.13
1988	22.21	5.34	5.80	6.38
1989	21.75	5.32	5.53	6.28
1990	22.39	5.45	5.99	6.90
1991	22.34	5.56	6.20	7.26
1992	22.23	5.76	6.43	7.66
1993	21.94	5.97	6.72	8.16
1994	21.90	6.19	7.01	8.63
1995	21.84	6.35	7.29	9.12
1996	21.87	6.75	7.72	9.69
1997	21.96	6.91	8.03	10.15
1998	22.14	7.05	8.34	10.64
1999	22.26	7.34	8.63	11.05
2000	22.43	7.48	8.87	11.34
2005	22.75	7.99	9.49	12.13
2010	23.00	8.27	9.80	12.54
2015	23.28	8.58	10.18	13.01

Source: (1980-1986) DOE *Monthly energy review*, July, 1987.

(1987-2000) DOE/EIA *Annual energy outlook*, 1989

(2001-2015) Ratio to 2000 from DOE/CE-0239,

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* 3412 Btu/kWh

Residential Energy Prices

Past energy prices (1980-1986) are from the DOE *Monthly energy review*, July, 1987. Projected energy prices (1987-2000) are from DOE *Annual energy outlook*, 1989. Extrapolation of energy prices (2001-2015) assumes average annual increases of: \$0.057 per million Btu (0.3% of year 2000 price) for electricity; \$0.073 per million Btu (1.0%) for natural gas; \$0.087 per million Btu (1.0%) for distillate; and \$0.111 per million Btu (1.0%) for LPG.

Electricity prices are further adjusted to reflect differences in effective price by specific end-uses. Table 4.6 shows multipliers for obtaining effective prices for space heating, water heating, air conditioning, and other end-uses. The multiplier for dishwashers, clothes washers, and clothes dryers is 1.10.

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 1978 and 1979 Residential Energy Consumption Surveys.

Table 4.6. Relative Electricity Price by End-Use
(Average Residential Electricity Price = 1.00)

Space heating	0.77
Water heating	0.87
Air conditioning	1.13
Other end-uses	1.10

Source: LBL-REM

Average Equipment Lifetime

The rates at which appliances retire (as a function of years since purchase) are taken from data provided by the Association of Home Appliance Manufacturers. Equipment lifetimes shown in Table 4.7 are from the same source.

Table 4.7. Average Equipment Lifetime (Years)

Dishwashers	12.6
Clothes washers	14.1
Clothes dryers	17.1

Source: AHAM

4.2 BASE CASE PROJECTIONS

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

4.2.1 New Appliance Unit Energy Consumptions (UECs)

Annual unit energy consumption of new appliances is projected based upon a set of designs available (each design characterized by a purchase price and an energy factor), and a market discount rate derived from implicit decision-making in recent purchase decisions for the product. The energy factor is a measure of the energy efficiency of the technology, as determined using the DOE test procedure, corrected for 1988 field usage. The method of correcting for actual usage behavior in households is explained in Section 4.2.4.

Average energy factors for new dishwashers and clothes washers sold in each past year (1980-1988) are obtained from industry sources. Similar data were not available for clothes dryers, because FTC EnergyGuide labels are not required. The LBL-REM produces projections of annual energy consumption of new appliances after 1988. Tables 4.8 (dishwashers), 4.9 (clothes washers), and 4.10 (clothes dryers) show the annual unit energy consumption projections.

Dishwashers. The average unit energy consumption for new units in two classes shows a 8% decrease from 1981 to 1988 (standard water heating and compact). The UEC for new standard dishwashers shows a 5% decrease from 1981 to 1988. The UECs are projected to decrease an additional 0.1% and 6%, respectively, for standard and standard water heating dishwashers, from 1988 to 2015. The UECs for compact dishwashers are projected to be unchanged from 1988 to 2015.

Table 4.8. Base-Case Projection of Unit Energy Consumption
For New Dishwashers

Year	Efficiency Factor		UEC (kWh/year)	
	Class 1 (Standard)	Class 2 (Standard, water heating)	Class 1 (Standard)	Class 2 (Standard, water heating)
1981	0.33	0.35	968	907
1984	0.36	0.38	901	843
1987	0.36	0.38	898	841
1990	0.37	0.38	886	835
1993	0.37	0.38	885	833
1996	0.37	0.38	884	832
2000	0.37	0.38	883	831
2005	0.40	0.43	799	751
2010	0.40	0.43	799	751
2015	0.40	0.43	799	751

Source: (1980-1987) AHAM
(1988-2015) LBL-REM

Clothes washers. The average UEC of new units increased 6% and 5%, respectively, for the two classes from 1981 to 1987. The base case projection begins in 1988, with UEC similar to the average for 1986. The average UEC of clothes washers is projected to decrease 18% and 12% from 1987 to 2015, respectively, for class 1 and class 2.

Table 4.9. Base Case Projection of Unit Energy Consumption
For New Clothes Washers

Year	Efficiency Factor		UEC (kWh/year)	
	Class 1 (top-loading, standard)	Class 2 (top-loading, large)	Class 1 (top-loading, standard)	Class 2 (top-loading, large)
1981	1.07	0.94	939	1316
1984	1.09	0.96	920	1291
1987	1.02	0.90	982	1377
1990	1.10	0.98	912	1265
1993	1.14	1.00	879	1235
1996	1.16	1.02	862	1219
2000	1.17	1.03	852	1203
2005	1.24	1.15	809	1073
2010	1.24	1.15	809	1073
2015	1.24	1.15	809	1073

Source: (1980-1987) AHAM
(1988-2015) LBL-REM

Table 4.10. Base-Case Projection of Unit Energy Consumption
For New Clothes Dryers

Year	Efficiency Factor		UEC	
	Electric	Gas	(kWh/yr)	(10 ⁶ Btu/yr)
1980	2.69	2.41	-	-
1981	2.69	2.42	1119	4.1
1984	2.69	2.45	1119	4.1
1987	2.69	2.48	1119	4.0
1990	2.84	2.49	1059	4.0
1993	2.84	2.49	1059	4.0
1996	2.84	2.82	1059	3.5
2000	2.84	2.82	1059	3.5
2005	2.84	2.82	1059	3.5
2010	3.23	2.82	933	3.5
2015	3.23	2.82	933	3.5

Source: (1980) AHAM
(1981-2015) LBL-REM

Clothes dryers. No time series of energy factors for average new units is available for dryers that is like the series presented for clothes washers and dishwashers. Electric clothes dryers are projected to be more efficient after 1987; gas clothes dryers show a slight efficiency increase in 1985 and a greater efficiency increase in 1996 (based on the projected increase in residential gas prices).

4.2.2 Efficiency Distributions

For each class of appliances, the range of UECs or efficiencies currently available (1988) is determined from industry sources, such as trade publications or directories. In future years, the relative distribution of efficiencies around the projected average is assumed to be similar to the current distribution. Standards diminish the range of available models and alter the shape of the distribution.

Dishwashers and clothes washers. The current distribution of UECs is taken from the data submitted by manufacturers to the FTC for the appliance labeling program. These distributions are presented in Appendix B.

Clothes dryers. Because these products are not part of the federal appliance labeling program, no comparable data set to the distribution of models for clothes washers and dishwashers is available. No distribution is assumed; instead, all shipments in each year are taken to be of a single design option.

4.2.3 Annual Appliance Installations

The market for appliances is considered to have two segments: new construction and existing housing. All new households are considered eligible to purchase each appliance. The pool of potential purchasers among existing households each year is defined as households that retired a unit that year, plus 5% of households that did not previously own the product.

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

The projection for the early period (1980-1987) is calibrated to reasonable agreement with available data, including domestic shipments and surveys of appliance ownership, e.g., from NAHB and Bureau of the Census, respectively.

Dishwashers. Annual installations of dishwashers are projected to increase from 3.6 million in 1987 to 4.8 million in 2015. (see Table 4.11). The share of sales attributable to replacement increases over time.

Clothes washers. Annual installations of clothes washers increase from 5.3 million in 1987 to 6.8 million in 2015.

Clothes dryers. Annual installations of clothes dryers increase from 3.9 million in 1987 to 5.0 million in 2015. Most of the increase is in electric dryers, which have 3.1 million annual installations in 1987 increasing to 4.0 million in 2015; gas dryers increase from 841,000 in 1987 to 945,000 in 2015. Tables 4.11 and 4.12 show the significant trends in the installation and saturation of these products.

Table 4.11. Annual Installations of New Dishwashers, Clothes Washers, and Clothes Dryers in U.S. Households (Thousands)

Year	Dishwashers	Clothes Washers	Clothes Dryers		
			Electric	Gas	Total
1981	2681	4767	2336	655	2991
1984	3492	5349	2937	796	3733
1987	3634	5355	3086	841	3927
1990	3846	5677	3304	886	4190
1993	4013	5823	3423	905	4328
1996	4020	5907	3475	860	4335
2000	4250	6109	3609	876	4485
2005	4479	6412	3786	898	4684
2010	4653	6599	3860	930	4790
2015	4837	6769	4011	945	4956

Source: (1981-2015) LBL-REM

4.2.4 Annual Residential Energy Consumption

Annual residential energy consumption for each product is calculated each year as the product of:

- number of occupied households;
- fraction of households owning the appliance;
- average unit energy consumption (engineering estimate); and
- usage behavior factor.

Table 4.12. Percent of Occupied U.S. Housing Units Having Dishwashers, Clothes Washers, and Clothes Dryers

Year	Dishwasher	Clothes Washer	Clothes Dryers		
			Electric	Gas	Total
1981	44	72	49	14	63
1984	45	76	51	14	65
1987	48	79	53	14	67
1990	49	81	55	15	70
1993	50	83	56	15	71
1996	52	85	58	15	73
2000	53	87	60	15	75
2005	55	89	61	15	76
2010	56	90	63	16	79
2015	57	91	64	15	79

Source: (1981-2015) LBL-REM

Results are expressed in quadrillion Btu of primary energy using a conversion factor for electricity of 1 kWh per 11,500 Btu. They are shown in Table 4.13.

Table 4.13. Annual Residential Energy Consumption
for Dishwashers, Clothes Washers, and Clothes Dryers
(Quadrillion Btu, primary energy)

Year	Dishwasher	Clothes Washer	Clothes Dryers		Total
			Electric	Gas	
1981	0.311	0.644	0.419	0.045	0.464
1984	0.324	0.695	0.486	0.049	0.535
1987	0.302	0.714	0.491	0.046	0.537
1990	0.307	0.736	0.518	0.047	0.565
1993	0.314	0.750	0.542	0.049	0.591
1996	0.322	0.761	0.566	0.050	0.616
2000	0.335	0.775	0.592	0.048	0.640
2005	0.341	0.778	0.623	0.048	0.671
2010	0.346	0.777	0.630	0.048	0.678
2015	0.354	0.782	0.632	0.049	0.681
1993-2015	7.76	17.77	13.90	1.11	15.01

Source: LBL-REM

4.2.5 Price of Purchased Appliances

Prices of new units increase with energy efficiency improvements. Table 4.14 shows shipment-weighted average prices.

Table 4.14. Unit Purchase Price of New Appliances
(1987 Dollars)

Year	Dishwasher	Clothes Washer	Clothes Dryers	
			Electric	Gas
1981	320	411	300	340
1984	324	412	300	340
1987	324	410	300	340
1990	325	412	300	340
1993	325	414	300	340
1996	325	416	300	359
2000	325	416	300	359
2005	332	428	300	359
2010	332	428	319	359
2015	332	428	319	359

Source: LBL-REM

4.3 SENSITIVITY ANALYSIS OF THE BASE CASE

The sensitivity cases selected are defined as follows:

1. *Lower Baseline Equipment Price.* The price of the baseline unit for each class is reduced 15%.
2. *Lower Incremental Equipment Price.* The incremental price associated with each engineering level is reduced by the uncertainty interval estimated for that incremental cost.
3. *Higher Baseline Equipment Price.* The price of the baseline unit for each class is increased 15%.
4. *Higher Incremental Equipment Price.* The incremental price associated with each engineering level is increased by the uncertainty interval estimated for the incremental cost.
5. *Lower Energy Price.* Assume lower energy prices, per *Annual energy outlook 1989*, "Low Oil Price, High Demand Case".
6. *Higher Energy Price.* Assume higher energy prices, per *Annual energy outlook, 1989*, "High Oil Price, Low Demand Case".
7. *High Equipment Efficiency.* Assume continuing future improvement in appliance efficiencies. For dishwashers, unit energy consumption decreases 2% per year; for clothes washers, 2% per year; for electric clothes dryers, 2% per year; and for gas clothes dryers, 2% per year.
8. *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 eight sensitivity cases are presented in the following tables. Tables 4.15 through 4.17 show how the average prices of dishwashers, clothes washers, and clothes dryers vary among the cases. Tables 4.18 through 4.20 show the differences in unit energy consumption or efficiency. The first line of these tables give the results of the reference case described in the previous section; the rest of the lines give the corresponding results of the sensitivity cases listed above.

Table 4.15. Average Purchase Price of New Dishwashers
(1987 Dollars)

Year:	1987	1993	1996	2005	2015
Reference	318	319	320	320	320
1	271	273	273	273	274
2	316	323	323	323	323
3	365	366	366	367	367
4	320	322	323	323	324
5	318	319	320	320	320
6	318	319	320	320	320
7	318	328	335	349	349
8	318	319	327	327	330

Source: LBL-REM

Table 4.16. Average Purchase Price of New Clothes Washers
(1987 Dollars)

Year:	1987	1993	1996	2005	2015
Reference	420	432	433	436	437
1	360	373	373	376	378
2	412	422	422	424	425
3	420	432	433	436	438
4	427	443	443	447	450
5	420	432	433	436	437
6	420	432	433	436	437
7	420	437	447	482	515
8	420	432	433	436	437

Source: LBL-REM

Table 4.17. Average Purchase Price of New Electric Dryers
(1987 Dollars)

Year:	1987	1993	1996	2005	2015
Reference	304	304	304	304	304
1	259	259	259	259	259
2	303	308	308	308	308
3	304	322	322	322	322
4	305	305	305	305	305
5	304	304	304	304	304
6	304	304	304	304	304
7	304	331	375	449	528
8	304	304	311	311	311

Source: LBL-REM

Table 4.18. Average Purchase Price of New Gas Dryers
(1987 Dollars)

Year:	1987	1993	1996	2005	2015
Reference	347	347	347	347	353
1	296	296	296	296	302
2	346	346	350	350	350
3	347	364	364	364	364
4	348	348	348	348	348
5	347	347	347	347	353
6	347	347	347	353	353
7	347	380	412	412	412
8	347	347	347	353	353

Source: LBL-REM

Table 4.19. Average Unit Energy Consumption of New Dishwasher
(kWh/year)

Year:	1987	1993	1996	2005	2015
Reference	612	601	598	596	593
(Sensitivity cases 1,3,4,5, and 6 have the same values as the reference case.)					
2	612	542	542	542	542
7	612	555	523	487	487
8	612	601	555	555	542

Source: LBL-REM

Table 4.20. Average Unit Energy Consumption of New Clothes Washer
(kWh/year)

Year:	1987	1993	1996	2005	2015
Reference	721	660	657	651	645
(Sensitivity cases 1,2,4,5,6 and 8 have the same values as the reference case.)					
3	721	608	607	603	600
7	721	644	606	505	412

Source: LBL-REM

Table 4.21. Average Unit Energy Consumption of New Electric Dryer
(kWh/yr)

Year:	1987	1993	1996	2005	2015
Reference	883	880	880	880	880
(Sensitivity cases 1, 4, 5, and 6 have the same values as the reference case.)					
2	883	821	821	821	821
3	883	805	805	805	805
7	883	795	748	624	510
8	883	880	821	821	821

Source: LBL-REM

Table 4.22. Average Unit Energy Consumption of New Gas Dryer
(MMBtu/yr)

Year:	1987	1993	1996	2005	2015
Reference	3.49	3.49	3.49	3.49	3.28
(Sensitivity cases 1 and 5 have the same values as the reference case.)					
2	3.49	3.49	3.28	3.28	3.28
3	3.49	3.21	3.21	3.21	3.21
4	3.49	3.49	3.49	3.49	3.49
6 or 8	3.49	3.49	3.49	3.28	3.28
7	3.49	3.15	3.02	3.02	3.02

Source: LBL-REM

4.4 REFERENCES

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2. Sumichrast, M., Ahluwalia, G., Crist, D. 1986. *Historical state housing starts, 1967-1985*, National Association of Home Builders, Washington DC. (January).
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5. RESULTS OF THE LBL RESIDENTIAL ENERGY MODEL

The LBL-REM projects a number of economic and energy-use variables that are used to assess the impact of proposed standards on consumers, electric utilities, and appliance manufacturers. This chapter presents the model's projections, assuming various trial standards. The principal outputs from the LBL-REM for each year are: unit equipment price and operating expense by product, projected annual shipments of residential appliances, energy consumption by end-use and fuel, and differences in these quantities between a base case and each trial standards case. These outputs are provided annually (or for selected years) and cumulatively over a period of time, i.e., 1993-2015. Energy savings are given for each year from implementation of standards to the end of the period. Net present value of standards is evaluated for each regulated product, and for the end-use(s) comprising the regulated and competing products. The sensitivity of the outputs to the key assumptions and data is analyzed; the results of this analysis are also presented.

The first three sections of this chapter present the output from the LBL-REM for each of the product types. The fourth section discusses the results of the sensitivity analysis. An overview of the methodology, assumptions, and data that go into the model is found in Chapter 2. Appendix B contains a more detailed description of the LBL-REM.

5.1 DISHWASHERS

5.1.1 Standards Levels

Table 5.1 shows the correspondence between the trial standards levels, the engineering design levels, and the associated unit energy consumption.

5.1.2 Energy Consumption

Table 5.2 shows the past and projected average energy uses of new dishwashers. The weighted average is obtained by taking the product of unit energy consumption for each class times a class-specific weighting factor, then summing over the classes. The weighting factors are: 0.363 for standard (115V) dishwashers, 0.619 for standard water-heating (115V) dishwashers, and 0.018 for compact water-heating (115V) dishwashers.

The unit energy consumption of the average new dishwasher (calculated at 1988 field usage) declines from 665 kWh/year, for units bought in 1981, to 601 kWh/year in 1993, in the absence of standards.

Table 5.3 presents projections of changes in total energy consumption of residential dishwashers at trial standards levels. Standards for dishwashers are projected to produce cumulative energy savings for the period 1993-2015; the savings range from 0.42 Quads for standards level 1 to 0.99 Quads for standards level 5 (see Table 5.3).

Table 5.1. Trial Standard Levels for Dishwashers

	Trial Standard Level				
	1	2	3	4	5
Engineering design option:					
Standard (115V)	1	2	5	6	7
Standard, water-heating (115V)	1	1	2	3	4
Compact, water-heating (115V)	1	1	2	3	4
Maximum annual energy consumption (DOE test procedure):					
Standard	840	823	722	705	688
Standard, water-heating	751	751	722	705	688
Compact, water-heating	558	558	538	522	510
Maximum annual energy consumption (1988 field usage):					
Standard	598	585	514	501	490
Standard, water-heating	534	534	513	501	490
Compact, water-heating	397	397	383	371	363

Table 5.2. Annual Energy Consumption New Dishwashers
(Weighted Average kWh/year)

		Trial Standard Level				
Year	Base	1	2	3	4	5
Past						
1981	665					
1984	629					
1987	612					
Projected						
1990	608					
1993	601	548	544	510	498	487
1996	598	547	544	510	498	487
2000	597	547	543	509	498	487
2015	593	546	542	509	498	487

Source: (1980-1987) Association of Home Appliance Manufacturers (AHAM), (1988-2015) LBL-REM

**Table 5.3. Annual Energy Consumption for Residential Dishwashers
(Quadrillion Btu, Primary)**

Year	Trial Standards Level					
	Base	1	2	3	4	5
1993	0.284	0.283	0.283	0.282	0.281	0.281
1996	0.288	0.281	0.280	0.275	0.273	0.271
2000	0.296	0.282	0.280	0.271	0.266	0.261
2005	0.313	0.291	0.289	0.274	0.267	0.261
2010	0.330	0.304	0.302	0.285	0.277	0.269
2015	0.346	0.319	0.316	0.289	0.289	0.281
1993-2015	7.16	6.74	6.70	6.43	6.29	6.17
Savings	-	0.42	0.46	0.73	0.87	0.99
(Percent of Base)	-	6%	6%	10%	12%	14%

Source: LBL-REM

5.1.3 Annual Installations

As shown in Table 5.4, installations of dishwashers decrease at higher standards levels. This result is a function of market share elasticities, the change in operating expense, and the change in equipment price resulting from higher standards. If there are no imports or exports, then annual installations are equivalent to domestic shipments. Domestic shipments can be calculated as annual installations, less imports, plus exports. The projection shows a 2.0% decrease from base to standards level 5 for cumulative shipments of dishwashers from 1993-2015.

**Table 5.4. Cumulative Installations of Residential Dishwashers
(Millions)**

Year	Trial Standard Level					
	Base	1	2	3	4	5
1993-2015	104.9	104.5	104.4	104.1	103.7	102.8
Change from Base	-	-0.4	-0.5	-0.8	-1.2	-2.1
Percent Change	-	-0.4%	-0.5%	-0.8%	-1.1%	-2.0%

Source: LBL-REM

5.1.4 Appliance Prices

Projections of the purchase prices in 1987 dollars for new dishwashers are shown in Table 5.5. The prices typically increase when standards come into effect.

Table 5.5. Projected Purchase Price of the Average
New Residential Dishwasher
(1987 Dollars per Unit)

Year	Base	Trial Standard Level				
		1	2	3	4	5
1987	318					
1990	318					
1993	319	325	327	331	337	349
1996	320	325	327	331	337	349
2000	320	325	327	331	337	349
2005	320	325	327	331	337	349
2010	320	325	327	331	337	349
2015	321	325	327	331	337	349

Source: LBL-REM

5.1.5 Net Present Value

The net present value to consumers of standards for any product is calculated by first determining the difference in present value of unit life-cycle costs between the base case and standards case each year. That difference is then multiplied by the standards case shipments for the year. The net present value for the period (1993-2015) is the sum over the years of the annual values. A positive net present value of standards results when the new units in the standards case have lower present value of life-cycle cost than do new units in the base case. Table 5.6 shows the net present value to consumers of the trial standards levels.

Life-cycle costs include purchase price of the appliance and operating expenses, including energy and water. The economic value of the water is taken to be the water cost plus wastewater treatment cost per gallon, and is included in the life-cycle costs and net present value. According to a recent report these costs are nearly equal, their sum totaling \$1.96 per thousand gallons in 1986 averaged over 100 major cities in the U.S., at typical residential consumption quantities, excluding fixed costs. (1)

**Table 5.6. Net Present Value to Consumers of Standards
for Dishwashers Purchased from 1993-2015
(1987 Dollars, Discounted to 1987 at 7% Real)**

	Trial Standard Level					
	Base	1	2	3	4	5
Net Present Value (Million 1987 \$)	-	300	327	272	434	129

Source: LBL-REM

5.1.6 Water Consumption

Water consumption between 1993 and 2015 for residential dishwashers is projected to be 2.97 trillion gallons in the base case (Table 5.7). Trial standards reduce water consumption by reducing the amount of water used per cycle in dishwashers. In 1988, a new dishwasher consumed about 10.8 gallons of water per cycle, or 2,470 gallons per year. Total residential water consumption averaged 110,000 gallons per household per year, of which about 17,300 gallons (16%) are heated.

**Table 5.7. Water Consumption for Residential
Dishwashers, 1993-2015**

	Trial Standard					
	Base	1	2	3	4	5
Water consumed (billion gallons)	2972	2748	2746	2739	2733	2661
Cumulative savings	-	224	226	233	239	311
(Percent of base)	-	8%	8%	8%	8%	10%

5.2 CLOTHES WASHERS

5.2.1 Standards Levels

Table 5.8 shows the correspondence between the trial standards levels, the engineering design levels, and the associated unit energy consumption.

Table 5.8. Trial Standards Levels for Clothes Washers

	Trial Standards Level				
	1	2	3	4	5
Engineering design option:					
Top-loading, standard	2	3	5	6	8
Top-loading, compact	2	3	5	6	8
Maximum annual energy consumption (DOE test procedure):					
Top-loading, standard	920	905	871	352	339
Top-loading, compact	670	656	631	196	189
Maximum annual energy consumption (1988 field usage):					
Top-loading, standard	674	660	653	262	259
Top-loading, compact	495	482	477	146	145

5.2.2 Energy Consumption

Table 5.9 shows the past and projected average energy uses of new clothes washers. The weighted average is obtained by taking the product of unit energy consumption for each class times a class-specific weighting factor, then summing over the classes. The weighting factors are: 0.96 for top-loading standard clothes washers, and 0.04 for top-loading compact clothes washers.

The unit energy consumption of the average new clothes washer (with 1988 field usage) is projected to decrease from 721 kWh/yr for units bought in 1987, to 660 kWh/year in 1993 in the absence of amended standards.

Table 5.10 presents projections of total energy savings for residential clothes washers. Standards for clothes washers are projected to produce cumulative energy savings during the period 1993-2015, ranging from 0.57 Quads for standards level 1 to 5.92 Quads for standards level 5.

5.2.3 Annual Installations

As shown in Table 5.11, installations* of clothes washers decrease at all standards levels. This result is a function of the change in operating expense, change in equipment price, and market share elasticities. The projection shows a 1.0% change from base to standards level 4 for cumulative shipments of clothes washers from 1993-2015.

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

Table 5.9. Annual Energy Consumption of New Clothes Washers (Weighted Average kWh/year)

		Trial Standards Level				
Year	Base	1	2	3	4	5
Past						
1981	721					
1984	721					
1987	721					
Projected						
1990	662					
1993	660	608	602	598	257	255
1996	657	607	601	597	257	255
2005	651	603	598	594	257	255
2015	645	601	595	592	257	255

Source: (1980-1987) AHAM,
(1988-2015) LBL-REM

5.2.4 Appliance Prices

Projections of the purchase prices for new clothes washers in 1987 dollars are shown in Table 5.12. The prices typically increase when standards come into effect.

5.2.5 Net Present Value

The net present value to consumers of standards for any product is calculated by first determining the difference in present value of unit life-cycle costs between the base case and standards case each year. That difference is then multiplied by the standards case shipments for the year. The net present value for the period (1993-2015) is the sum over the years of the annual values. A positive net present value of standards results when the new units in the standards case have lower present value of life-cycle cost than do new units in the base case. Table 5.13 shows the net present value to consumers of the trial standards levels.

5.2.6 Water Consumption

Water consumption for residential clothes washers during the period 1993-2015 is projected to be 23 trillion gallons in the base case. Trial standards reduce the amount of hot water used per cycle for clothes washers and to a lesser extent, reduce the total water consumption. In 1988, a new clothes washer consumed about 32 gallons of water per cycle, or 12,200 gallons per year. About 31% of this water is heated. (Total residential water consumption averaged 110,000 gallons per household per year, of which about 17,300 gallons (16%) are heated.) xxxxx

Table 5.10. Annual Energy Consumption for Residential Clothes Washers (Quadrillion Btu, Primary)

Year	Base	Trial Standards Level				
		1	2	3	4	5
1993	0.512	0.510	0.509	0.509	0.493	0.493
1996	0.511	0.501	0.499	0.496	0.414	0.410
2000	0.515	0.495	0.492	0.487	0.322	0.314
2005	0.530	0.499	0.494	0.487	0.235	0.223
2010	0.546	0.510	0.503	0.496	0.189	0.174
2015	0.560	0.523	0.515	0.508	0.178	0.161
Cumulative 1993-2015	12.18	11.61	11.50	11.37	6.49	6.26
Savings	-	0.57	.68	.81	5.69	5.92
(Percent of Base)	-	5%	6%	7%	47%	49%

Source: LBL-REM

Table 5.11. Cumulative Installations of Residential Clothes Washers (Millions)

Year	Base	Trial Standards Level				
		1	2	3	4	5
1993-2015	145.8	145.7	145.4	143.8	105.4	95.0
Change from Base	-	-0.1	-0.4	-2.0	-40.4	-50.8
Percent Change	-	-0.1%	-0.3%	-1.4%	-27.7%	-34.8%

Source: LBL-REM

Table 5.12. Projected Purchase Price of the Average New Residential Clothes Washer (1987 Dollars per Unit)

Year	Base	Trial Standards Level				
		1	2	3	4	5
1987	420					
1990	432					
1993	432	432	438	454	567	598
2005	436	436	441	455	567	598
2015	438	438	431	456	567	598

Source: LBL-REM

**Table 5.13. Net Present Value to Consumers of Standards
for Clothes Washers Purchased from 1993-2015
(1987 Dollars, Discounted to 1987 at 7% Real)**

	Trial Standards Level					
	Base	1	2	3	4	5
Net Present Value (Million 1987 \$)	-	528	508	-135	1294	196

Source: LBL-REM

**Table 5.14. Water Consumption for Residential Clothes
Washer, 1993-2015**

	Trial Standard					
	Base	1	2	3	4	5
Water cons. (billion gal.)	23240	23234	23194	23015	15639	14901
Cum. savings	-	6	46	225	7601	8339
(% base)	-	0.03%	0.2%	1%	33%	36%

5.3 CLOTHES DRYERS

5.3.1 Standards Levels

Table 5.15 shows the correspondence between the trial standards levels, the engineering design levels, and the associated unit energy consumption.

5.3.2 Energy Consumption

Tables 5.16 to 5.17 show the past and projected average energy uses of new clothes dryers, for electric and gas, respectively. The unit energy consumption (at 1988 usage) of the average new electric clothes dryer is projected to change from 902 kWh/year for units bought in 1981, to 880 kWh/year in 1993 in the absence of standards. The unit energy consumption of the average new gas clothes dryer is projected to remain 4.1 MMBtu/year for units bought in 1981 through 1993 in the absence of amended standards.

Table 5.15. Trial Standards Levels for Clothes Dryers

	Trial Standards Level				
	1	2	3	4	5
Engineering design option:					
Electric	1	2	3	4	5
Gas	1	2	3	3	3
Maximum annual energy consumption (DOE test procedure):					
Electric-standard (kWh/yr)	986	966	908	715	338
Electric-compact (115V) (kWh/yr)	407	399	375	295	140
Electric-compact (240) (kWh/yr)	439	431	405	319	151
Gas (10 ⁶ Btu/yr)	3.80	3.73	3.50	3.50	3.50
Maximum annual energy consumption (1988 usage):					
Electric-standard (kWh/yr)	851	834	784	617	292
Electric-compact (115V) (kWh/yr)	351	344	323	255	120
Electric-compact (240) (kWh/yr)	379	372	349	275	130
Gas (10 ⁶ Btu/yr)	3.28	3.22	3.02	3.02	3.02

Table 5.18 presents projections of total energy consumption of residential electric and gas clothes dryers. In the base case, annual energy consumption for clothes dryers increases from 0.571 Quads in 1993 to 0.714 Quads in 2015. The rise is due to an increasing number of households owning these products.

Table 5.18 presents projections of energy savings for clothes dryers. Standards for clothes dryers are projected to produce cumulative energy savings during the period 1993-2015 ranging from 0.6 Quads for standards level 1 to 6.39 Quads for standards level 4, and correspond to a 4%-46% of base-case clothes dryer energy use.

5.3.3 Annual Installations

As shown in Table 5.19 installations* of clothes dryers decrease at all trial standards levels. This result is a function of the change in operating expense, change in equipment price, and market share elasticities. The projection shows a -26% change from base to standards level 5 for cumulative shipments of clothes dryers from 1993 to 2015.

The impact on shipments is fuel-specific. For trial standards levels 4 and 5, gas dryer installations increase and electric dryer installations decrease.

The trial standard levels must be analyzed in pairs, one each for electric and gas dryers. This is necessary because consumers can choose between electric and gas dryers, so a standard on one affects the installations of the other.

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

Table 5.16. Annual Energy Consumption of New Electric Clothes Dryers
(kWh/year)

		Trial Standard Level				
Year	Base	1	2	3	4	5
Past						
1981	902					
1984	892					
1987	883					
Projected						
1990	880					
1993	880	822	805	757	596	282
1996	880	822	805	757	596	282
2005	880	822	805	757	596	282
2015	880	822	805	757	596	282

Source: LBL-REM

Table 5.17. Annual Energy Consumption of New Gas Clothes Dryers
(10⁶ Btu/year)

		Trial Standard Level				
Year	Base	1	2	3	4	5
Past						
1981	3.50					
1984	3.50					
1987	3.50					
Projected						
1990	3.50					
1993	3.50	3.30	3.20	3.00	3.00	3.00
1996	3.50	3.30	3.20	3.00	3.00	3.00
2000	3.50	3.30	3.20	3.00	3.00	3.00
2005	3.50	3.30	3.20	3.00	3.00	3.00
2015	3.30	3.30	3.20	3.00	3.00	3.00

Source: LBL-REM

5.3.4 Appliance Prices

Projections of the purchase prices for new clothes dryers in 1987 dollars are shown in Tables 5.20 to 5.21. The prices typically increase when standards come into effect.

Table 5.18. Annual Energy Consumption of Residential Clothes Dryers (Quadrillion Btu, Primary; based on 1988 usage)

Year	Trial Standards Level					
	Base	1	2	3	4	5
1993	.571	.569	.569	.567	.561	.554
1996	.593	.583	.580	.568	.536	.495
2000	.619	.599	.593	.569	.503	.417
2005	.653	.622	.612	.576	.471	.332
2010	.685	.646	.633	.588	.454	.273
2015	.714	.670	.656	.606	.455	.247
1993-2015	14.84	14.23	14.02	13.32	11.23	8.45
Electric	13.63	13.05	12.87	12.23	10.00	7.02
Gas	1.21	1.18	1.16	1.09	1.23	1.43
Energy savings (total)	-	0.61	0.82	1.52	3.61	6.39
(electricity)	-	0.58	0.76	1.40	3.63	6.61
(gas)	-	0.03	0.05	0.12	-0.02	-0.22
Percent Change (total)	-	4%	6%	10%	24%	46%

Source: LBL-REM

Table 5.19. Cumulative Installations of Residential Clothes Dryers during the Period 1993-2015 (Millions)

Year	Trial Standards Level					
	Base	1	2	3	4	5
Electric	86.6	86.4	86.1	84.2	73.6	59.0
Gas	21.6	21.6	21.4	20.5	25.2	32.0
Total	108.2	108.0	107.5	104.7	98.8	91.0
Change from Base:						
Electric		-0.2	-0.5	-2.4	-13.0	-27.6
Gas		0	-0.2	-1.1	+3.6	+10.4
Total		-0.2	-0.7	-3.5	-9.4	-17.2
Percent change from Base:						
Electric		0%	-1%	-3%	-15%	-57%
Gas		0%	-1%	-5%	+17%	+99%
Total		0%	-1%	-3%	-9%	-26%

Source: LBL-REM

**Table 5.20. Projected Purchase Price of the Average
New Residential Electric Clothes Dryer
(1987 Dollars per Unit)**

Year	Base	Trial Standards Level				
		1	2	3	4	5
1987	304					
1990	304					
1993	304	311	322	370	465	568
2005	304	311	322	370	465	568
2015	304	311	322	370	465	568

Source: LBL-REM

**Table 5.21. Projected Purchase Price of the Average
New Residential Gas Clothes Dryer
(1987 Dollars per Unit)**

Year	Base	Trial Standards Level				
		1	2	3	4	5
1987	347					
1990	347					
1993	347	353	364	412	412	412
1996	347	353	364	412	412	412
2005	347	353	364	412	412	412
2015	353	353	364	412	412	412

Source: LBL-REM

5.3.5 Net Present Value

The net present value to consumers of standards for any product is calculated by first determining the difference in present value of unit life-cycle costs between the base case and standards case each year. That difference is then multiplied by the standards case shipments for the year. The net present value for the period (1993-2015) is the sum over the years of the annual values. A positive net present value of standards results when the new units in the standards case have lower present value of life-cycle cost than do new units in the base case. Table 5.22 shows the net present value to consumers of the trial standards levels.

**Table 5.22. Net Present Value to Consumers of Standards
for Clothes Dryers Purchased from 1993 to 2015
(1987 Dollars, Discounted to 1987 at 7% Real)**

	Base	Trial Standards Level				
		1	2	3	4	5
Net Present Value (Million 1987 \$):						
Electric	-	1212	1292	1009	1811	1285
Gas	-	51	9	-231	-284	-479
Total	-	1263	1301	778	1527	806

Source: LBL-REM

5.4 SENSITIVITY ANALYSIS

The base case and standards levels as described above constitute a reference case against which the impacts of standards under different assumptions may be compared. The sensitivity analysis is performed by running the LBL-REM for the base case and trial standards level 3 for dishwashers, trial standards level 3 for clothes washers, and trial standards level 2 for clothes dryers. For each sensitivity case, the results for the trial standards level are compared to the corresponding base-case run and the differences are tabulated.

The assumptions in the eight sensitivity cases are described in Section 4.3 and listed in Table 5.23. Tables 5.24 through 5.26 show results for cumulative energy consumption. The sensitivity analysis of product shipments is given in Tables 5.27 through 5.29. Tables 5.30 shows the consumer net present values. The first line of these tables gives the results of the reference case (base case, standards level, and difference). The rest of the lines each give the results corresponding to one of the eight sensitivity cases, including the base case, standards case, and difference. Note that the changes in the impact of standards as a function of the changed assumptions (difference between the base and standards cases) are the principal results of the sensitivity analysis.

Table 5.23. Sensitivity Analysis Cases

Case	Description
1	Lower Baseline Equipment Price
2	Lower Incremental Equipment Price
3	Higher Baseline Equipment Price
4	Higher Incremental Equipment Price
5	Lower Energy Price
6	Higher Energy Price
7	High Equipment Efficiency
8	Market Discount Rates Decline

Table 5.24. Cumulative Energy Consumption of Residential Dishwashers during the Period 1993-2015 (Quadrillion Btu, Primary)

Case	Trial Standard		
	Base	Level 4	Difference
Reference	7.16	6.29	0.87
1	7.15	6.28	0.88
2	6.59	6.19	0.40
3	7.16	6.30	0.86
4	7.15	6.26	0.89
5	7.16	6.30	0.86
6	7.16	6.29	0.87
7	6.27	6.16	0.12
8	6.82	6.27	0.55

Source: LBL-REM

Table 5.25. Cumulative Energy Consumption of Clothes Washers during the Period 1993-2015 (Quadrillion Btu, Primary)

Case	Trial Standard		
	Base	Level 1	Difference
Reference	12.18	11.61	0.58
1	12.17	11.59	0.58
2	12.20	11.62	0.58
3	12.19	11.61	0.58
4	12.17	11.59	0.58
5	12.19	11.61	0.58
6	12.19	11.61	0.58
7	10.73	10.57	0.16
8	12.18	11.60	0.58

Source: LBL-REM

Table 5.26. Cumulative Energy Consumption of Residential Clothes Dryers during the Period 1993-2015 (Quadrillion Btu, Primary)

Case	Trial Standard		
	Base	Level 2	Difference
Reference	14.84	14.02	0.82
1	14.84	14.01	0.83
2	14.11	13.91	0.21
3	14.84	14.03	0.81
4	14.84	14.00	0.84
5	14.85	14.02	0.82
6	14.84	14.02	0.81
7	12.21	12.21	0.00
8	14.32	14.02	0.29

Source: LBL-REM

Table 5.27. Cumulative Shipments of Residential Dishwashers during the Period 1993-2015 (Millions)

Case	Trial Standard		Difference
	Base	Level 4	
Reference	104.9	103.7	-1.1
1	104.8	103.4	-1.4
2	104.7	104.3	-0.4
3	104.9	104.0	-0.9
4	104.7	103.0	-1.6
5	104.9	103.8	-1.1
6	104.8	103.7	-1.1
7	103.1	103.0	-0.1
8	104.4	103.6	-0.8

Source: LBL-REM

Table 5.28. Cumulative Shipments of Residential Clothes Washers during the Period 1993-2015 (Millions)

Case	Trial Standard		Difference
	Base	Level 1	
Reference	145.8	145.7	-0.1
1	145.6	145.6	0.0
2	146.0	146.0	0.0
3	145.9	145.9	0.0
4	145.5	145.5	0.0
5	145.8	145.8	0.0
6	145.8	145.7	-0.1
7	138.9	138.9	0.0
8	145.8	145.7	-0.1

Source: LBL-REM

Table 5.29. Cumulative Shipments of Residential Clothes Dryers during the Period 1993-2015 (Millions)

Case	Trial Standard		Difference
	Base	Level 2	
Reference	108.2	107.5	-0.7
1	108.2	107.3	-0.9
2	108.1	107.7	-0.4
3	108.3	107.6	-0.6
4	108.2	107.3	-1.0
5	108.3	107.5	-0.7
6	108.2	107.5	-0.7
7	100.4	100.4	0.0
8	108.1	107.5	-0.6

Source: LBL-REM

**Table 5.30. Total Consumer Net Present Value
for Units Sold during the Period 1993-2015
(Discounted to 1987 at 7% Real)**

Case	Net Present Value (Million \$)			
	Dishwasher Trail Standard	Clothes Washer Trail Standard	Electric Dryer Trail Standard	Gas Dryer Trail Standard
	Level 4	Level 1	Level 2	Level 2
Reference	434	528	1293	9
1	436	527	1290	9
2	206	533	164	-6
3	433	528	1294	9
4	214	522	1172	2
5	409	508	1248	19
6	456	544	1325	1
7	44	152	-0	0
8	212	527	263	-23

Source: LBL-REM

5.5 REFERENCES

1. Arthur Young Environmental Consulting Group. 1986. "1986 National water and wastewater rate survey", New York (May).

6. LIFE-CYCLE COSTS AND PAYBACK PERIODS

The effect of standards on consumers includes a change in operating expense (usually decreased) and a change in purchase price (usually increased). The net effect is analyzed by three methods:

- life-cycle cost (LCC);
- payback period (PBP);
- cost of conserved energy (CCE).

6.1 Life-Cycle Cost

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

$$LCC = PC + \sum_{t=1}^N \frac{OC_t}{(1+r)^t} \quad (6.1)$$

If operating expenses are constant over time, Eq. (6.1) simplifies to

$$LCC = PC + PWF \cdot OC, \quad (6.2)$$

where we have defined the present worth factor:

$$PWF = \sum_{t=1}^N \frac{1}{(1+r)^t} = \frac{1}{r} \left[1 - \frac{1}{(1+r)^N} \right] \quad (6.3)$$

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

The impact of standards is calculated as the difference in LCC, base case minus standards case. If the LCC difference is greater than zero (positive savings), then the standard provides a net decrease in expenses to the consumer. That is, the present value of decreased operating expenses offsets the increased purchase price. Conversely, if the LCC difference is negative, the standard causes a net increase in expenses to the consumer.

6.1.1 LCC Data Inputs

The purchase price is based on the factory costs in the Engineering Analysis and includes a factory markup plus a distributor and retailer markup. Purchase price and installation cost are added to the present value of operating expenses (including maintenance, if applicable), discounted and summed over the life of the product. Expenses in future years are discounted to the year of purchase, 1993. The discount rate is 7% real, with sensitivity analysis performed at 2% and 15% real.

The energy price is the projected 1993 average residential energy price times the end-use factor (explained in Chapter 4). Usage assumptions are based on the P&G field survey: 229 cycles per year for dishwashers, 380 cycles per year for clothes washers, and 359 cycles per year for clothes dryers.

For dishwashers and clothes washers, much of the operating expense comes from heating water before it enters these products. The water heating energy required, and its cost, depend upon the fuel-type and efficiency of the water heater. For these reasons, two sets of life-cycle costs are presented - one for electric water heaters, and one for gas water heaters. Water heater seasonal efficiencies are used: 85% for electric, 52% for gas.

6.1.2 LCC Results

Figures 6.1 to 6.14 show the LCCs by design option, using discount rates of 2%, 7%, and 15% real. The values used to produce these figures are presented in Section 6.1.3, Numerical Examples.

Tables 6.1 to 6.3 show the LCC differences by standard level. The results are the weighted average of LCC differences comparing that portion of the projected distribution of designs in the base case which are less efficient than the standard level to the design at the standard level. (Designs with energy consumption at or below the standard level are not affected by the standard, so these are excluded from the calculation of impacts.) These LCCs are calculated at a 7% discount rate; a higher discount rate (e.g., 10%) gives a smaller difference.

Table 6.1 shows for standard electric clothes dryers, all standard levels lower the LCC relative to the base case. For compact electric clothes dryers, standard levels 1 and 2 lower the LCCs. For standard gas clothes dryers, standard level 1 lowers the LCC.

Table 6.2 shows for clothes washers, all standard levels lower LCC, except level 5 for clothes washers served by gas water heaters.

Table 6.3 shows that all standard levels for dishwashers lower LCCs.

Table 6.1. Life-Cycle Cost Difference (in 1987 \$)*

Clothes Dryers

Class	Level 1	Level 2	Level 3	Level 4	Level 5
Standard Electric	76.8	42.2	32.3	66.2	90.0
Compact Electric (120V)	24.1	10.3	-22.4	-64.2	-188.2
Compact Electric (240V)	27.0	11.1	-20.3	-57.9	-173.6
Standard Gas	12.1	-1.5	-39.3	-39.3	-39.3

* Base-minus-standards case calculated at a 7% consumer discount rate

Table 6.2. Life-Cycle Cost Difference (in 1987 \$)*

Clothes Washers

Class	Level 1	Level 2	Level 3	Level 4	Level 5
with Electric Water Heating					
Standard	106.3	89.1	52.8	287.1	225.6
Compact	105.0	90.6	63.7	168.6	108.0
with Gas Water Heating					
Standard	43.0	34.8	2.3	81.5	42.6
Compact	42.5	35.0	6.1	33.0	-3.0

* Base-minus-standards case in 1993 calculated at a 7% consumer discount rate

Table 6.3. Life-Cycle Cost Difference (in 1987 \$)*

Dishwashers

Class	Level 1	Level 2	Level 3	Level 4	Level 5
with Electric Water Heating					
Standard	87.8	59.4	94.5	96.5	92.1
Standard Water-Heating	74.5	74.5	52.0	49.3	45.8
Compact	48.1	48.1	54.6	55.8	50.1
with Gas Water Heating					
Standard	34.3	24.3	22.0	24.0	15.5
Standard Water-Heating	33.0	33.0	28.9	28.3	20.2
Compact	19.3	19.3	25.8	27.0	17.8

* Base-minus-standards case in 1993 calculated at a 7% consumer discount rate

Figure 6.1. Life-Cycle Cost of Design Options for
Standard Non-Water Heating Dishwashers

**Life-Cycle Cost for a
Standard Dishwasher 115V
229 cycles/year (P&G 1988 data)**

Figure 6.2. Life-Cycle Cost of Design Options for Standard Non-Water Heating Dishwashers

Life-Cycle Cost for a Standard Water Heating Dishwasher 115V 229 cycles/year (P&G 1988 data)

Figure 6.3. Life-Cycle Cost of Design Options for
Standard Water-Heating Dishwashers

Life-Cycle Cost for a Standard Water Heating Dishwasher 115V 229 cycles/year (P&G 1988 data)

Figure 6.4. Life-Cycle Cost of Design Options for
Standard Water-Heating Dishwashers

Figure 6.5. Life-Cycle Cost of Design Options for Compact Dishwashers

**Life-Cycle Cost for a
Compact Dishwasher 115V
229 cycles/year (P&G 1988 data)**

Figure 6.6. Life-Cycle Cost of Design Options for Compact Dishwashers

**Life-Cycle Cost for a
Standard Clothes Washer 115V (2.6 cu. ft.)
380 cycles/year (P&G 1988 data)**

Figure 6.7. Life-Cycle Cost of Design Options for Standard Clothes Washers

Life-Cycle Cost for a Standard Clothes Washer 115V (2.6 cu. ft.) 380 cycles/year (P&G 1988 data)

Figure 6.8. Life-Cycle Cost of Design Options for Standard Clothes Washers

**Life-Cycle Cost for a
Compact Clothes Washer 115V (1.45 cu. ft.)
380 cycles/year (P&G 1988 data)**

Figure 6.9. Life-Cycle Cost of Design Options for Compact Clothes Washers

Life-Cycle Cost for a Compact Clothes Washer 115V (1.45 cu. ft.) 380 cycles/year (P&G 1988 data)

Figure 6.10. Life-Cycle Cost of Design Options for Clothes Washer

Figure 6.11. Life-Cycle Cost of Design Options for
Standard Electric Clothes Dryers

Figure 6.12. Life-Cycle Cost of Design Options for Compact Electric Clothes Dryers (120V)

Figure 6.13. Life-Cycle Cost of Design Options for Compact Electric Clothes Dryers (240V)

**Life-Cycle Cost for a
Standard Gas Dryer
359 cycles/year (P&G 1988 data)**

Figure 6.14. Life-Cycle Cost of Design Options for
Standard Gas Clothes Dryers

dollars are in \$1987

416	Clothes Washer (cycle/yr)
416	Clothes Dryer (cycle/yr)
322	Dishwasher (cycle/yr)

1993 elec price (\$/MMBtu)	6.8731
1993 gas price (\$/MMBtu)	5.7305
water cost (\$/gal)	0.001957

Test Proc eff. elec WH	100.00%
Test Proc eff. gas WH	75.00%
elec WH/(elec+gas WH)	44.00%
gas WH/(elec+gas WH)	56.00%

Standard Clothes Washers 115V, Capacity 2.6 cu.-ft.

Standard Clothes Washers 115V, Capacity 2.6 cu.ft.										
Design Options	UEC (kWh/yr)	Price (\$87)	With Electric Water Heating			With Gas Water Heating				
			Annual Cost /year	Life Cycle Cost 2% 7% 15%	Annual Cost /year	Life Cycle Cost 2% 7% 15%				
0 Baseline 5 Settings	1258	400.04	126.5	1941	1511	1126	65.8	1202	978	778
1 Eliminate Warm/Warm Set.	1047	400.04	109.8	1738	1365	1030	60.3	1135	930	746
2 Eliminate Warm Rinse	920	400.04	99.3	1616	1277	973	57.0	1095	901	727
3 2 + Improv. Motor	905	411.70	98.7	1614	1278	978	55.8	1092	902	732
4 3 + Therm. Mix. Valve (1)	875	432.28	96.3	1605	1278	985	55.0	1103	916	748
5 4 + Plastic Tub	871	441.82	95.9	1610	1284	992	54.9	1111	924	757
6 2 + Horizontal Axis	352	570.89	46.4	1136	978	837	31.1	949	844	749
7 6 + Therm. Mix. Valve (1)	414	591.57	45.5	1146	992	853	30.8	966	862	768
8 7 + Plastic Tub	339	601.12	45.4	1154	1000	862	30.7	975	871	777

Compact Clothes Washers 115V, Capacity 1.45 cu. ft.

compact Clothes Washers 115V, Capacity 1.45 cu.ft.												
Design Options	UEC (kWh/yr)	Price (\$87)	With Electric Water Heating			With Gas Water Heating						
			Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%	Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%				
0 Baseline 5 Settings	906	310.03	88.2	10.4	1384	1084	816	45.7	4.8	867	711	572
1 Eliminate Warm/Warm Set.	758	310.03	76.5	8.7	1242	982	749	41.8	4.2	820	677	550
2 Eliminate Warm Rinse	670	310.03	69.5	7.7	1157	920	709	39.5	3.8	792	657	537
3 2 + Improv. Motor	656	321.69	68.4	7.5	1155	922	714	38.4	3.6	790	659	542
4 3 + Therm. Mix. Valve (1)	635	342.27	66.7	7.3	1155	928	725	37.9	3.5	804	675	560
5 4 + Plastic Tub	632	351.81	66.5	7.3	1162	936	733	37.8	3.5	812	684	569
6 2 + Horizontal Axis	196	480.88	25.9	2.3	796	708	629	17.3	1.1	692	633	580
7 6 + Therm. Mix. Valve (1)	190	501.56	25.4	2.2	811	725	647	17.2	1.1	711	652	600
8 7 + Plastic Tub	189	511.11	25.3	2.2	820	733	656	17.1	1.1	720	661	609

Life Cycle Costs based on DOE test procedure

Standard Electric Dryer

Design Options	UEC (kWh/yr)	Price (\$87)	Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%
0 Baseline	1120	300.03	88.5	12.9	1571 1167 836
1 Automatic Termination	986	313.01	77.9	11.3	1432 1076 785
2 1 + Insulation	966	323.72	76.3	11.1	1420 1071 786
3 2 + Recycle Exhaust	908	372.34	71.8	10.4	1403 1075 807
4 2 + Microwave (1)	715	467.45	56.5	8.2	1279 1021 810
5 2 + Heat Pump	338	695.31	26.7	3.9	1079 957 857

Compact Electric Dryer (120V)

Design Options	UEC (kWh/yr)	Price (\$87)	Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%
0 Baseline	462	250.03	36.5	5.3	775 608 471
1 Automatic Termination	407	263.01	32.2	4.7	725 578 458
2 1 + Insulation	399	273.71	31.5	4.6	726 582 465
3 2 + Recycle Exhaust	375	322.33	29.6	4.3	748 612 502
4 2 + Microwave (1)	295	417.44	23.3	3.4	752 646 559
5 2 + Heat Pump	140	645.31	11.0	1.6	804 753 712

Compact Electric Dryer (240V)

Design Options	UEC (kWh/yr)	Price (\$87)	Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%
0 Baseline	499	280.03	39.5	5.7	847 666 519
1 Automatic Termination	439	293.01	34.7	5.1	792 633 503
2 1 + Insulation	431	303.71	34.0	5.0	792 637 510
3 2 + Recycle Exhaust	405	352.34	32.0	4.7	812 666 546
4 2 + Microwave (1)	319	447.44	25.2	3.7	809 694 600
5 2 + Heat Pump	151	675.31	11.9	1.7	846 792 747

Standard Gas Dryer

Design Options	UEC (MMBtu/yr)	Price (\$87)	Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%
0 Baseline	4.32	340.03	24.9	4.3	696 582 490
1 Automatic Termination	3.80	353.02	21.8	3.8	666 566 485
2 1 + Insulation	3.73	363.72	21.3	3.7	670 573 493
3 2 + Recycle Exhaust	3.50	412.34	20.1	3.5	701 609 534

Life Cycle Costs based on DOE test procedure

Standard Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	With Electric Water Heating			With Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%	Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%
0 Baseline	1006	300.03	87.0	11.6	1261	1013	781	43.1 776 653 538
1 Reduce Water Use	840	310.81	72.4	9.7	1111	904	711	37.3 723 617 517
2 1 + Improv. Motor	823	317.15	71.0	9.5	1101	899	709	35.9 713 611 515
3 2 + Booster Heater (1)	734	332.37	64.0	8.4	1039	857	686	36.7 738 633 535
4 3 + Fill Control	717	345.03	62.5	8.2	1035	857	690	36.0 742 640 544
5 1 + Booster Heater (2)	722	325.99	63.1	8.3	1023	843	674	35.8 721 619 524
6 5 + Improv. Motor	705	332.28	61.7	8.1	1014	838	673	34.4 712 614 522
7 6 + Fill Control	688	344.95	60.2	7.9	1010	839	677	33.7 717 621 531

Standard Water Heating Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	With Electric Water Heating			With Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%	Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%
0 Baseline	894	320.03	78.2	10.3	1183	961	752	44.1 807 681 563
1 Reduce Water Use	751	330.81	65.4	8.6	1052	866	692	38.1 751 643 541
2 1 + Reduce Booster Use (1)	722	333.72	63.0	8.3	1030	850	682	35.7 728 627 531
3 2 + Improv. Motor	704	339.91	61.6	8.1	1020	845	680	34.3 719 621 529
4 3 + Fill Control	687	352.43	60.1	7.9	1017	845	684	33.7 724 628 538

Compact Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	With Electric Water Heating			With Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%	Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%
0 Baseline	657	260.03	57.1	7.6	891	728	575	33.5 630 535 445
1 Reduce Water Use	558	270.81	48.3	6.4	804	666	537	29.4 595 512 433
2 1 + Reduce Booster Use (1)	538	273.71	46.7	6.2	789	656	531	27.8 580 501 427
3 2 + Improv. Motor	522	279.90	45.4	6.0	781	652	531	26.5 573 497 426
4 3 + Fill Control	510	292.43	44.4	5.9	782	656	537	26.1 580 506 436

Life Cycle Costs based on Field Usage (Procter & Gamble 1988)

dollars are in \$1987	(\$87)
Clothes Washer (cycle/yr)	380
Clothes Dryer (cycle/yr)	359
Dishwasher (cycle/yr)	229
1993 elec price (\$/MMBtu)	6.8731
1993 gas price (\$/MMBtu)	5.7305
water cost (\$/gal)	0.001957
Stock eff. elec WH	85.00%
Stock eff. gas WH	52.00%
elec WH/(elec&gas WH)	44.00%
gas WH/(elec&gas WH)	56.00%

Standard Clothes Washers 115V, Capacity 2.6 cu.ft.

Design Options	UEC (kWh/yr)	Price (\$87)	With Electric Water Heating			With Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%	Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%
0 Baseline 5 Settings	950	400.04	111.7	12.6	1760 1381 1041	64.7	6.7	1188 968 771
1 Eliminate Warm/Warm Set.	746	400.04	92.7	9.9	1530 1215 932	57.1	5.4	1095 901 727
2 Eliminate Warm Rinse	674	400.04	86.0	8.9	1447 1155 893	54.3	4.9	1062 877 712
3 2 + Improv. Motor	660	411.53	84.9	8.8	1446 1157 899	53.2	4.8	1060 879 717
4 3 + Plastic Tub	657	421.07	84.6	8.7	1452 1164 906	53.1	4.7	1068 887 726
5 4 + Therm. Mix. Valve (1)	653	441.79	84.3	8.7	1468 1182 925	53.0	4.7	1087 907 746
6 2 + Horizontal Axis	262	570.86	40.5	3.4	1064 927 803	29.2	2.0	926 827 738
7 6 + Plastic Tub	260	580.41	40.4	3.4	1072 935 812	29.1	2.0	935 836 747
8 7 + Therm. Mix. Valve (1)	259	601.14	40.3	3.4	1092 955 832	29.1	2.0	955 857 768

Compact Clothes Washers 115V, Capacity 1.45 cu.ft.

Design Options	UEC (kWh/yr)	Price (\$87)	With Electric Water Heating			With Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%	Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%
0 Baseline 5 Settings	688	310.03	77.8	9.1	1258 993 756	44.9	5.0	857 705 568
1 Eliminate Warm/Warm Set.	546	310.03	64.6	7.2	1096 877 680	39.6	4.1	792 658 537
2 Eliminate Warm Rinse	495	310.03	59.8	6.5	1039 835 653	37.7	3.7	769 641 526
3 2 + Improv. Motor	482	321.53	58.8	6.4	1038 838 659	36.7	3.6	768 644 532
4 3 + Plastic Tub	480	331.06	58.6	6.3	1045 846 667	36.6	3.6	777 652 541
5 4 + Therm. Mix. Valve (1)	477	351.78	58.3	6.3	1062 864 686	36.5	3.5	796 672 561
6 2 + Horizontal Axis	146	480.85	22.6	1.9	756 679 610	16.3	1.1	679 624 574
7 6 + Plastic Tub	145	490.40	22.5	1.9	765 688 620	16.2	1.1	688 633 584
8 7 + Therm. Mix. Valve (1)	144	511.13	22.4	1.9	785 708 640	16.2	1.1	709 654 604

Life Cycle Costs based on Field Usage (Procter & Gamble 1988)

Standard Electric Dryer

Design Options	UEC (kWh/yr)	Price (\$87)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	967	300.03	76.4	11.1	1397	1048	763
1 Automatic Termination	851	313.01	67.2	9.8	1279	971	720
2 1 + Insulation	834	323.72	65.9	9.6	1270	969	723
3 2 + Recycle Exhaust	784	372.34	61.9	9.0	1262	979	747
4 2 + Microwave (1)	617	467.45	48.8	7.1	1168	945	763
5 2 + Heat Pump	292	695.31	23.1	3.4	1027	921	835

Compact Electric Dryer (120V)

Design Options	UEC (kWh/yr)	Price (\$87)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	399	250.03	31.5	4.6	703	559	441
1 Automatic Termination	351	263.01	27.7	4.0	662	535	431
2 1 + Insulation	344	273.71	27.2	4.0	664	540	438
3 2 + Recycle Exhaust	323	322.33	25.6	3.7	689	573	477
4 2 + Microwave (1)	255	417.44	20.1	2.9	706	614	539
5 2 + Heat Pump	120	645.31	9.5	1.4	782	739	703

Compact Electric Dryer (240V)

Design Options	UEC (kWh/yr)	Price (\$87)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	431	280.03	34.1	5.0	769	614	486
1 Automatic Termination	379	293.01	30.0	4.4	723	586	474
2 1 + Insulation	372	303.71	29.4	4.3	725	591	482
3 2 + Recycle Exhaust	349	352.34	27.6	4.0	749	623	520
4 2 + Microwave (1)	275	447.44	21.7	3.2	760	660	579
5 2 + Heat Pump	130	675.31	10.3	1.5	823	776	738

Standard Gas Dryer

Design Options	UEC (MMBtu/yr)	Price (\$87)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	3.7280	340.03	21.4	3.7	647	549	469
1 Automatic Termination	3.2806	353.02	18.8	3.3	623	537	467
2 1 + Insulation	3.2150	363.72	18.4	3.2	628	544	475
3 2 + Recycle Exhaust	3.0221	412.34	17.3	3.0	661	582	517

Life Cycle Costs based on Field Usage (Procter & Gamble 1988)

Standard Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	With Electric Water Heating			With Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%	Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%
0 Baseline	716	300.03	70.1	9.4	1074	875	37.5	5.3
1 Reduce Water Use	598	310.81	58.1	7.8	952	787	32.0	4.5
2 1 + Improv. Motor	585	317.14	57.1	7.7	948	785	31.0	4.4
3 2 + Booster Heater (1)	522	332.36	50.7	6.7	892	748	30.3	4.2
4 3 + Fill Control	510	345.03	49.4	6.6	891	750	29.7	4.1
5 1 + Booster Heater (2)	514	325.98	50.0	6.7	878	736	29.7	4.1
6 5 + Improv. Motor	501	332.27	49.0	6.5	873	734	28.7	4.0
7 6 + Fill Control	490	344.96	47.8	6.4	873	737	28.1	3.9

Standard Water Heating Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	With Electric Water Heating			With Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%	Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%
0 Baseline	636	320.03	62.0	8.2	1005	828	36.6	5.1
1 Reduce Water Use	534	330.81	51.6	6.9	900	754	31.3	4.3
2 1 + Reduce Booster Use (1)	513	333.71	49.9	6.6	885	743	29.6	4.1
3 2 + Improv. Motor	500	339.90	48.9	6.5	880	741	28.6	3.9
4 3 + Fill Control	489	352.43	47.7	6.3	879	744	28.1	3.9

Compact Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	With Electric Water Heating			With Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%	Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%
0 Baseline	467	260.03	45.1	6.0	757	629	27.5	3.8
1 Reduce Water Use	397	270.80	37.9	5.1	689	581	23.8	3.3
2 1 + Reduce Booster Use (1)	383	273.71	36.7	4.9	679	575	22.7	3.1
3 2 + Improv. Motor	371	279.89	35.8	4.8	675	573	21.8	3.0
4 3 + Fill Control	363	292.43	35.0	4.7	679	579	21.4	3.0

6.2 Payback Period

The payback period measures the amount of time it takes to recover the additional consumer investment in increased efficiency through lower operating costs. It is found by solving the equation

$$\Delta PC + \sum_{i=1}^{PAY} \Delta OC_i = 0 \quad (6.4)$$

for PAY . In general, PAY is found by interpolating between the two years when the expression in Eq. (6.4) changes sign. If the operating cost is constant, the equation has the simple solution

$$PAY = -\frac{\Delta PC}{\Delta OC} \quad (6.5)$$

Numerically, the payback period is the ratio of the increase in purchase (and installation) price from the base to the standards cases to the decrease in annual operating expenditures (including maintenance).

Payback periods are expressed in years. A payback period of 3 years means that the increased purchase price is equal to 3 times the value of reduced operating expenses achieved in the year of purchase, or that the increased purchase price is recovered in approximately 3 years due to lower operating expenses. (Payback periods greater than the life of the product mean that the increased purchase price is not recovered in reduced operating expenses.)

Two sets of data on payback periods are presented in this chapter: those for individual design options for each appliance class, and the payback to the average consumer of each standard level as compared to the base case. Tables 6.1. through 6.9 contain information on both the incremental and cumulative payback periods for design options. Incremental paybacks are those associated with adding a single design option to the previous level. Cumulative paybacks are those associated with adding the design options at the given level to those in typical models projected to be produced in the base case in 1993.

The payback periods by standard level (Tables 6.13 to 6.18) are the weighted average comparing that portion of the projected distribution of designs in the base case which are less efficient than the standard level to the design at the standard level. (Designs with energy consumption at or below the standard level are not affected by the standard, so these are excluded from the calculation of impacts.)

6.2.1 Payback Period Data Inputs

The purchase price is based on the factory costs in the Engineering Analysis and includes a factory markup plus a distributor and retailer markup. Purchase price and installation cost are added to the present value of operating expenses (including maintenance, if applicable), discounted and summed over the life of the product.

For dishwashers and clothes washers, much of the operating expense comes from heating water before it enters these products. The water heating energy required, and its cost, depend upon the fuel-type and efficiency of the water heater. For these reasons, two sets of results are presented - one for electric water heaters, and one for gas water heaters.

The energy price is the projected 1993 average residential energy price times the end-use factor (explained in Chapter 4). When usage assumptions are based on the DOE test procedure,

water heater recovery efficiencies are used: 100% for electric, 75% for gas. The DOE test assumes 322 cycles per year for dishwashers, 416 cycles per year for clothes washers, and 416 cycles per year for clothes dryers. (See Tables 6.4 to 6.12, and 6.16 to 6.18.)

When usage assumptions are based on the P&G field survey, water heater seasonal efficiencies are used: 85% for electric, 52% for gas. The field survey indicates 229 cycles per year for dishwashers, 380 cycles per year for clothes washers, and 359 cycles per year for clothes dryers. (See Tables 6.13 to 6.15.)

Tables 6.13 through 6.18 present the average payback periods associated with setting standards at the trial levels. Tables 6.13 to 6.15 assume P&G usage, while Tables 6.16 to 6.18 assume the DOE test. In general, the payback periods based on field usage are higher than payback periods based on the DOE test, because field usage has less cycles per year, and/or less hot water usage than the DOE test. Standard levels with payback periods less than 3 years in Tables 6.16 to 6.18 meet the rebuttable presumption test for economic justification. (For example, standard levels 1 through 4 for standard clothes washers served by electric water heaters.)

Table 6.4. Payback Periods of Design Options (Years)
Standard Dishwashers

Standard Level	Design Option	Consumer Price (\$1987)	with Elec. Water Heating		with Gas Water Heating	
			Energy Expense (\$1987)	Payback Period Incr. Cumul.	Energy Expense (\$1987)	Payback Period Incr. Cumul.
	0 Baseline	300.0	70.1	NA	37.5	NA
1	1 Reduce Water Use	310.8	58.1	0.9	32.0	2.0
2	2 1 + Improved Motor	317.1	57.1	6.3	31.0	6.3
	3 2 + Booster Heater	332.4	50.7	2.4	30.3	24.3
	4 3 + Fill Control	345.0	49.4	10.1	29.7	19.7
3	5 1 + Booster Heater	326.0	50.0	1.9	29.7	6.6
4	6 5 + Improved Motor	332.3	49.0	6.3	28.7	6.3
5	7 6 + Fill Control	345.0	47.8	10.5	28.1	21.4
1993 Base Case Average:		307.8	63.6		34.6	

Table 6.5. Payback Periods of Design Options (Years)
Standard Water Heating Dishwashers

Standard Level	Design Option	Consumer Price (\$1987)	with Elec. Water Heating		with Gas Water Heating	
			Energy Expense (\$1987)	Payback Period Incr. Cumul.	Energy Expense (\$1987)	Payback Period Incr. Cumul.
	0 Baseline	320.0	62.0	NA	36.6	NA
1,2	1 Reduce Water Use	330.8	51.6	1.0	31.3	2.0
3	2 1 + Reduce Booster Use	333.7	49.9	1.8	29.6	1.8
4	3 2 + Improved Motor	339.9	48.9	6.2	28.6	6.2
5	4 3 + Fill Control	352.4	47.7	10.4	28.1	21.2
1993 Base Case Average:		325.9	56.6		33.8	

Table 6.6. Payback Periods of Design Options (Years)
Compact Dishwashers

Standard Level	Design Option	Consumer Price (\$1987)	with Elec. Water Heating		with Gas Water Heating	
			Energy Expense (\$1987)	Payback Period Incr. Cumul.	Energy Expense (\$1987)	Payback Period Incr. Cumul.
	0 Baseline	260.0	45.1	NA	27.5	NA
1,2	1 Reduce Water Use	270.8	37.9	1.5	23.8	2.9
3	2 1 + Reduce Booster Use	273.7	36.7	2.5	22.7	2.5
4	3 2 + Improved Motor	279.9	35.8	6.9	21.8	6.8
5	4 3 + Fill Control	292.4	35.0	15.1	21.4	30.6
1993 Base Case Average:		260.0	45.1		27.5	

Table 6.7. Payback Periods of Design Options (Years)
Standard Clothes Washers

Standard Level	Design Option	Consumer Price (\$1987)	with Elec. Water Heating		with Gas Water Heating	
			Energy Expense (\$1987)	Payback Period Incr. Cumul.	Energy Expense (\$1987)	Payback Period Incr. Cumul.
	0 Baseline 5 Settings	400.0	111.7	NA	64.7	NA
1	1 Eliminate Warm/Warm Set.	400.0	92.7	0.0	57.1	0.0
2	2 Eliminate Warm Rinse	400.0	86.0	0.0	54.3	0.0
3	3 2 + Improv. Motor	411.5	84.9	10.7	53.2	10.6
4	4 3 + Plastic Tub	421.1	84.6	31.7	53.1	68.3
5	5 4 + Therm. Mix. Valve	441.8	84.3	60.8	53.0	172.7
6	6 2 + Horizontal Axis	570.9	40.5	3.8	29.2	6.8
7	7 6 + Plastic Tub	580.4	40.4	82.1	29.1	147.2
8	8 7 + Therm. Mix. Valve	601.1	40.3	182.2	29.1	737.3
1993 Base Case Average:		435.2	84.9		52.8	

Table 6.8. Payback Periods of Design Options (Years)
Compact Clothes Washers

Standard Level	Design Option	Consumer Price (\$1987)	with Elec. Water Heating		with Gas Water Heating	
			Energy Expense (\$1987)	Payback Period Incr. Cumul.	Energy Expense (\$1987)	Payback Period Incr. Cumul.
	0 Baseline 5 Settings	310.0	77.8	NA	44.9	NA
1	1 Eliminate Warm/Warm Set.	310.0	64.6	0.0	39.6	0.0
2	2 Eliminate Warm Rinse	310.0	59.8	0.0	37.7	0.0
3	3 2 + Improv. Motor	321.5	58.8	11.5	36.7	11.5
4	4 3 + Plastic Tub	331.1	58.6	43.5	36.6	89.1
5	5 4 + Therm. Mix. Valve	351.8	58.3	77.1	36.5	228.1
6	6 2 + Horizontal Axis	480.9	22.6	4.6	16.3	8.0
7	7 6 + Plastic Tub	490.4	22.5	152.7	16.2	221.2
8	8 7 + Therm. Mix. Valve	511.1	22.4	257.3	16.2	1411.5
1993 Base Case Average:		360.5	51.9		33.0	

Table 6.9. Payback Periods of Design Options (Years)
Standard Electric Clothes Dryers

Standard Level	Design Option	Consumer Price (\$1987)	Energy Expense (\$1987)	Payback Period	Incr.	Cumul.
	0 Baseline	300.0	76.4	NA	NA	
1	1 Automatic Termination	313.0	67.2	1.4	1.4	
2	2 1 + Insulation	323.7	65.9	8.0	2.3	
3	3 2 + Recycle Exhaust	372.3	61.9	12.3	5.0	
4	4 2 + Microwave	467.5	48.8	8.4	6.1	
5	5 2 + Heat Pump	695.3	23.1	8.7	7.4	

1993 Base Case Average:

306.3

72.0

Table 6.10. Payback Periods of Design Options (Years)
Standard Gas Dryer

Standard Level	Design Option	Consumer Price (\$1987)	Energy Expense (\$1987)	Payback Period	Incr.	Cumul.
	0 Baseline	340.0	21.4	NA	NA	
1	1 Automatic Termination	353.0	18.8	5.1	5.1	
2	2 1 + Insulation	363.7	18.4	28.5	8.1	
3,4,5	3 2 + Recycle Exhaust	412.3	17.3	44.0	17.9	

1993 Base Case Average:

347.1

20.0

Table 6.11. Payback Periods of Design Options (Years)
Compact 120V Electric Clothes Dryer

Standard Level	Design Option	Consumer Price (\$1987)	Energy Expense (\$1987)	Payback Period	Incr.	Cumul.
	0 Baseline	250.0	31.5	NA	NA	
1	1 Automatic Termination	263.0	27.7	3.4	3.4	
2	2 1 + Insulation	273.7	27.2	19.3	5.5	
3	3 2 + Recycle Exhaust	322.3	25.6	29.8	12.1	
4	4 2 + Microwave	417.4	20.1	20.3	14.7	
5	5 2 + Heat Pump	645.3	9.5	21.0	18.0	

1993 Base Case Average:

254.6

30.2

Table 6.12. Payback Periods of Design Options (Years)
Compact 240V Electric Clothes Dryers

Standard Level	Design Option	Consumer Price (\$1987)	Energy Expense (\$1987)	Payback Period	Incr.	Cumul.
	0 Baseline	280.0	34.1	NA	NA	
1	1 Automatic Termination	293.0	30.0	3.2	3.2	
2	2 1 + Insulation	303.7	29.4	17.9	5.1	
3	3 2 + Recycle Exhaust	352.3	27.6	27.6	11.2	
4	4 2 + Microwave	447.4	21.7	18.8	13.6	
5	5 2 + Heat Pump	675.3	10.3	19.5	16.6	

1993 Base Case Average:

285.4

32.4

Table 6.13. Payback Period (Years)
Clothes Dryers (with P & G Usage)

Class	Level 1	Level 2	Level 3	Level 4	Level 5
Standard Electric	1.4	2.9	6.6	6.9	8.0
Compact Electric (120V)	3.4	6.4	14.6	16.2	18.9
Compact Electric (240V)	3.2	6.1	14.1	15.2	17.7
Standard Gas	5.1	10.8	24.6	24.6	24.6

Table 6.14. Payback Period (Years)
Clothes Washers (with P & G Usage)

Class	Level 1	Level 2	Level 3	Level 4	Level 5
with Electric Water Heating					
Standard	0.0	1.0	3.8	3.1	3.7
Compact	0.0	1.0	3.5	4.1	5.1
with Gas Water Heating					
Standard	0.0	2.2	8.3	5.7	7.0
Compact	0.0	2.2	7.7	7.2	9.0

Table 6.15. Payback Period (Years)
Dishwashers (with P & G Usage)

Class	Level 1	Level 2	Level 3	Level 4	Level 5
with Electric Water Heating					
Standard	0.9	1.5	1.3	1.7	2.4
Standard Water-Heating	1.0	1.0	1.2	1.8	3.0
Compact	1.5	1.5	1.6	2.2	3.2
with Gas Water Heating					
Standard	2.0	2.9	3.7	4.2	5.7
Standard Water-Heating	2.0	2.0	1.9	2.7	4.7
Compact	2.9	2.9	2.8	3.5	5.3

Table 6.16. Payback Period (Years)
Clothes Dryers (with DOE Test Procedure)

Class	Level 1	Level 2	Level 3	Level 4	Level 5
Standard Electric	1.2	2.5	5.7	6.0	6.9
Compact Electric (120V)	3.0	5.5	12.6	14.0	16.3
Compact Electric (240V)	2.7	5.3	12.1	13.1	15.2
Standard Gas	4.4	9.3	21.2	21.2	21.2

Table 6.17. Payback Period (Years)
Clothes Washers (with DOE Test Procedure)

Class	Level 1	Level 2	Level 3	Level 4	Level 5
with Electric Water Heating					
Standard	0.0	0.8	2.7	2.6	3.2
Compact	0.0	0.9	2.9	3.6	4.4
with Gas Water Heating					
Standard	0.0	2.2	7.2	5.6	6.8
Compact	0.0	2.4	7.7	7.1	8.7

Table 6.18. Payback Period (Years)
Dishwashers (with DOE Test Procedure)

Class	Level 1	Level 2	Level 3	Level 4	Level 5
with Electric Water Heating					
Standard	0.7	1.2	1.1	1.4	2.0
Standard Water-Heating	0.8	0.8	0.9	1.4	2.3
Compact	1.2	1.2	1.3	1.7	2.5
with Gas Water Heating					
Standard	1.9	2.6	4.2	4.3	5.8
Standard Water-Heating	1.8	1.8	1.6	2.2	3.7
Compact	2.6	2.6	2.4	2.8	4.3

6.3 Cost of Conserved Energy (CCE)

The cost of conserved energy (CCE) is the increase in purchase price amortized over the lifetime of the appliance at the consumer discount rate divided by the annual energy savings:

$$CCE = -\frac{CRF \cdot \Delta PC}{\Delta E}, \quad (6.6)$$

where the capital recovery factor $CRF = 1/PWF$ is used to annualize the capital costs. Note that although the CCE can be measured in cents per kWh (or dollars per million Btu), it does not depend on current or future energy prices. The consumer will benefit whenever the cost of conserved energy is less than the price of energy for that end-use.

6.3.1 CCE Data Inputs

The data inputs for CCE calculations are the same as in Section 6.1.1, LCC data inputs.

6.3.2 CCE Results

Tables 6.19 through 6.21 present the cost of conserved energy of the standards levels as compared to the base case. Note that the current (1988) and projected (1993) average residential electricity prices are 7.27 and 7.19 cents per kWh, respectively (1). These are equivalent to 6.32 and 6.25 \$ per million Btu, respectively, where 1 kWh is taken as 11500 Btu primary energy. The residential price of natural gas was \$5.13 per million Btu in 1988 and is projected to be \$5.73 in 1993 (1).

Standard levels with CCEs less than projected costs of energy supply include all standard levels for standard electric clothes dryers, for all dishwashers, and for standard and compact clothes washers served by electric water heaters. Other examples are standard levels 1-4 for standard clothes washers served by gas water heaters, and standard levels 1-3 for compact clothes washers served by gas water heaters.

Standard levels with CCEs greater than projected costs of energy supply include standard levels 3-5 for compact electric clothes dryers, standard levels 2-5 for standard gas clothes dryers, standard level 5 for standard clothes washers served by gas water heaters, and standard levels 4-5 for compact clothes washers served by gas water heaters.

Table 6.19. Cost of Conserved Energy (\$/10⁶ Btu)
Clothes Dryers

Class	Level 1	Level 2	Level 3	Level 4	Level 5
Standard Electric	1.0	2.0	4.6	4.9	5.6
Compact Electric (120V)	2.4	4.5	10.3	11.4	13.3
Compact Electric (240V)	2.2	4.3	9.9	10.7	12.4
Standard Gas	3.0	6.3	14.4	14.4	14.4

Table 6.20. Cost of Conserved Energy (\$/10⁶ Btu)
Clothes Washers

Class	Level 1	Level 2	Level 3	Level 4	Level 5
with Electric Water Heating					
Standard	0.0	0.8	3.0	2.8	3.4
Compact	0.0	0.8	2.7	3.8	4.7
with Gas Water Heating					
Standard	0.0	1.5	5.6	5.4	6.6
Compact	0.0	1.5	5.2	6.8	8.5

Table 6.21. Cost of Conserved Energy (\$/10⁶ Btu)
Dishwashers

Class	Level 1	Level 2	Level 3	Level 4	Level 5
with Electric Water Heating					
Standard	0.8	1.4	1.2	1.5	2.1
Standard Water-Heating	0.8	0.8	0.9	1.3	2.1
Compact	1.4	1.4	1.5	2.0	2.9
with Gas Water Heating					
Standard	1.7	2.5	2.8	3.2	4.4
Standard Water-Heating	1.7	1.7	1.4	1.9	3.4
Compact	2.6	2.6	2.5	3.1	4.7

6.5 LCC Sensitivity Analysis

The sensitivity of the national LCC results were tested by varying assumptions about energy prices and equipment prices. These tables should be compared to the first set of tables in Section 6.1.3, "Numerical examples: LCCs".

Low and high energy prices were defined as the minimum and maximum, respectively, of the energy prices by Census region in the DOE/EIA *Annual energy outlook*, 1989.

Low and high equipment prices were defined as one standard deviation below and above, respectively, the equipment prices used elsewhere in this chapter. The standard deviations are presented as a percent in the tables, in the column labelled "Uncert.". (Note that the uncertainty in the baseline price is a percent of the total price, while the uncertainty in the price of other designs is applied to the incremental price of that design.)

The following sensitivity cases were analyzed:

- (1) Low (regional) energy prices and high equipment prices;
- (2) Low (regional) energy prices;
- (3) High equipment prices;
- (4) High (regional) energy prices and low equipment prices;
- (5) Low equipment prices;
- (6) High (regional) energy prices.

6.6 REFERENCES

1. U.S. Department of Energy, Energy Information Administration. 1989. *Annual energy outlook, 1989*, DOE/EIA-0383(89).

Sensitivity Case 1: Low Regional Energy Prices and High Equipment Prices
(with field usage)

dollars are in \$1987

Clothes Washer (cycle/yr)	380
Clothes Dryer (cycle/yr)	359
Dishwasher (cycle/yr)	229
1993 elec price (\$/MMBtu)	5.6968
1993 gas price (\$/MMBtu)	5.2793
water cost (\$/gal)	0.001957
Stock eff. elec WH	85.00%
Stock eff. gas WH	52.00%
elec WH/(elec+gas WH)	44.00%
gas WH/(elec+gas WH)	56.00%

Standard Clothes Washers 115V, Capacity 2.6 cu.ft.

Design Options	UEC (kWh/yr)	Price (\$87)	With Electric Water Heating			With Gas Water Heating		
			Annual Cost	Life Cycle 2%	Life Cycle Cost 7%	Annual Cost	Life Cycle 2%	Life Cycle Cost 7%
0 Baseline 5 Settings	950	460.05	96.8	12.6	1639	1310	1015	60.8
1 Eliminate Warm/Warm Set.	746	460.05	81.1	9.9	1448	1172	925	53.8
2 Eliminate Warm Rinse	674	460.05	75.5	8.9	1380	1123	893	51.2
3 2 + Improv. Motor	660	482.92	74.6	8.8	1392	1138	911	50.4
4 3 + Plastic Tub	657	497.23	74.4	8.7	1403	1150	924	50.2
5 4 + Therm. Mix. Valve (1)	653	528.31	74.1	8.7	1431	1179	953	50.1
6 2 + Horizontal Axis	262	665.03	36.5	3.4	1109	985	874	27.8
7 6 + Plastic Tub	260	679.36	36.4	3.4	1123	999	888	27.7
8 7 + Therm. Mix. Valve (1)	259	710.45	36.3	3.4	1153	1029	919	27.7

Compact Clothes Washers 115V, Capacity 1.45 cu.ft.

Design Options	UEC (kWh/yr)	Price (\$87)	With Electric Water Heating			With Gas Water Heating		
			Annual Cost	Life Cycle 2%	Life Cycle Cost 7%	Annual Cost	Life Cycle 2%	Life Cycle Cost 7%
0 Baseline 5 Settings	688	356.53	67.1	9.1	1174	946	741	41.9
1 Eliminate Warm/Warm Set.	546	356.53	56.1	7.2	1040	849	678	37.0
2 Eliminate Warm Rinse	495	356.53	52.2	6.5	992	815	656	35.2
3 2 + Improv. Motor	482	379.42	51.3	6.4	1005	830	674	34.4
4 3 + Plastic Tub	480	393.71	51.2	6.3	1017	843	687	34.3
5 4 + Therm. Mix. Valve (1)	477	424.79	50.9	6.3	1045	872	717	34.2
6 2 + Horizontal Axis	146	561.52	20.3	1.9	809	740	678	15.5
7 6 + Plastic Tub	145	575.84	20.3	1.9	823	754	692	15.5
8 7 + Therm. Mix. Valve (1)	144	606.94	20.2	1.9	853	785	723	15.4

Sensitivity Case 1: Low Regional Energy Prices and High Equipment Prices
(with field usage)

Standard Electric Dryer

Design Options	UEC (kWh/yr)	Price (\$87)	Annual Cost /year	MMBtu /year	Life Cycle Cost 2% 7% 15%
0 Baseline	967	360.04	63.3	11.1	1269 980 743
1 Automatic Termination	851	375.61	55.7	9.8	1176 921 713
2 1 + Insulation	834	389.00	54.6	9.6	1173 924 720
3 2 + Recycle Exhaust	784	461.93	51.3	9.0	1199 965 773
4 2 + Microwave (1)	617	604.59	40.4	7.1	1185 1000 849
5 2 + Heat Pump	292	884.00	19.1	3.4	1159 1071 1000

Compact Electric Dryer (120V)

Design Options	UEC (kWh/yr)	Price (\$87)	Annual Cost /year	MMBtu /year	Life Cycle Cost 2% 7% 15%
0 Baseline	399	300.04	26.1	4.6	675 556 458
1 Automatic Termination	351	315.61	23.0	4.0	646 541 455
2 1 + Insulation	344	328.99	22.5	4.0	653 550 465
3 2 + Recycle Exhaust	323	401.92	21.2	3.7	706 609 530
4 2 + Microwave (1)	255	544.58	16.7	2.9	784 708 646
5 2 + Heat Pump	120	824.00	7.9	1.4	937 901 872

Compact Electric Dryer (240V)

Design Options	UEC (kWh/yr)	Price (\$87)	Annual Cost /year	MMBtu /year	Life Cycle Cost 2% 7% 15%
0 Baseline	431	336.04	28.2	5.0	741 612 507
1 Automatic Termination	379	351.61	24.8	4.4	708 595 502
2 1 + Insulation	372	364.99	24.3	4.3	715 603 512
3 2 + Recycle Exhaust	349	437.93	22.9	4.0	767 662 576
4 2 + Microwave (1)	275	580.58	18.0	3.2	839 757 690
5 2 + Heat Pump	130	860.00	8.5	1.5	982 943 912

Standard Gas Dryer

Design Options	UEC (MMBtu/yr)	Price (\$87)	Annual Cost /year	MMBtu /year	Life Cycle Cost 2% 7% 15%
0 Baseline	3.7280	408.04	19.7	3.7	691 601 527
1 Automatic Termination	3.2806	423.62	17.3	3.3	672 593 529
2 1 + Insulation	3.2150	437.00	17.0	3.2	681 603 540
3 2 + Recycle Exhaust	3.0221	509.93	16.0	3.0	739 666 607

Sensitivity Case 1: Low Regional Energy Prices and High Equipment Prices
(with field usage)

Standard Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	<--- With Electric Water Heating			---><--- With Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2%	Annual Cost	MMBtu /year	Life Cycle Cost 2%
0 Baseline	716	360.04	59.0	9.4	1012	844	686	34.0
1 Reduce Water Use	598	374.37	48.9	7.8	914	775	644	28.9
2 1 + Improv. Motor	585	383.87	48.1	7.7	914	778	649	28.0
3 2 + Booster Heater (1)	522	404.11	42.7	6.7	876	754	640	27.2
4 3 + Fill Control	510	423.12	41.7	6.6	883	765	653	26.6
5 1 + Booster Heater (2)	514	397.78	42.2	6.7	863	743	631	26.6
6 5 + Improv. Motor	501	407.21	41.3	6.5	864	746	635	25.8
7 6 + Fill Control	490	426.25	40.3	6.4	872	757	649	25.2

Standard Water Heating Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	<--- With Electric Water Heating			---><--- With Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2%	Annual Cost	MMBtu /year	Life Cycle Cost 2%
0 Baseline	636	384.04	52.3	8.2	961	813	673	32.9
1 Reduce Water Use	534	398.37	43.5	6.9	879	755	638	27.9
2 1 + Reduce Booster Use (1)	513	402.23	42.1	6.6	867	747	635	26.6
3 2 + Improv. Motor	500	411.52	41.3	6.5	867	750	639	25.7
4 3 + Fill Control	489	430.31	40.3	6.3	875	760	653	25.2

Compact Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	<--- With Electric Water Heating			---><--- With Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2%	Annual Cost	MMBtu /year	Life Cycle Cost 2%
0 Baseline	467	312.04	38.0	6.0	731	623	522	24.5
1 Reduce Water Use	397	326.36	31.9	5.1	678	588	502	21.1
2 1 + Reduce Booster Use (1)	383	330.23	30.9	4.9	672	584	501	20.2
3 2 + Improv. Motor	371	339.50	30.2	4.8	673	587	506	19.4
4 3 + Fill Control	363	358.31	29.5	4.7	684	600	521	19.1

Sensitivity Case 2: Low Regional Energy Prices
(with field usage)

dollars are in \$1987

Clothes Washer (cycle/yr)	380
Clothes Dryer (cycle/yr)	359
Dishwasher (cycle/yr)	229
1993 elec price (\$/MMBtu)	5.6968
1993 gas price (\$/MMBtu)	5.2793
water cost (\$/gal)	0.001957
Stock eff. elec WH	85.00%
Stock eff. gas WH	52.00%
elec WH/(electgas WH)	44.00%
gas WH/(electgas WH)	56.00%

Standard Clothes Washers 115V, Capacity 2.6 cu.ft.

Design Options	UEC (kWh/yr)	Price (\$87)	With Electric Water Heating			With Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2%	Annual Cost	MMBtu /year	Life Cycle Cost 2%
0 Baseline 5 Settings	950	400.04	96.8	12.6	1579	60.8	6.7	1141
1 Eliminate Warm/Warm Set.	746	400.04	81.1	9.9	1388	53.8	5.4	1055
2 Eliminate Warm Rinse	674	400.04	75.5	8.9	1320	51.2	4.9	1024
3 2 + Improv. Motor	660	411.53	74.6	8.8	1320	50.4	4.8	1025
4 3 + Plastic Tub	657	421.07	74.4	8.7	1327	50.2	4.7	1033
5 4 + Therm. Mix. Valve (1)	653	441.79	74.1	8.7	1344	50.1	4.7	1052
6 2 + Horizontal Axis	262	570.86	36.5	3.4	1015	27.8	2.0	909
7 6 + Plastic Tub	260	580.41	36.4	3.4	1024	27.7	2.0	918
8 7 + Therm. Mix. Valve (1)	259	601.14	36.3	3.4	1043	27.7	2.0	939

Compact Clothes Washers 115V, Capacity 1.45 cu.ft.

Design Options	UEC (kWh/yr)	Price (\$87)	With Electric Water Heating			With Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2%	Annual Cost	MMBtu /year	Life Cycle Cost 2%
0 Baseline 5 Settings	688	310.03	67.1	9.1	1127	41.9	5.0	820
1 Eliminate Warm/Warm Set.	546	310.03	56.1	7.2	993	37.0	4.1	760
2 Eliminate Warm Rinse	495	310.03	52.2	6.5	946	35.2	3.7	739
3 2 + Improv. Motor	482	321.53	51.3	6.4	947	34.4	3.6	740
4 3 + Plastic Tub	480	331.06	51.2	6.3	954	34.3	3.6	749
5 4 + Therm. Mix. Valve (1)	477	351.78	50.9	6.3	972	34.2	3.5	768
6 2 + Horizontal Axis	146	480.85	20.3	1.9	729	15.5	1.1	670
7 6 + Plastic Tub	145	490.40	20.3	1.9	738	15.5	1.1	679
8 7 + Therm. Mix. Valve (1)	144	511.13	20.2	1.9	757	15.4	1.1	699

Sensitivity Case 2: Low Regional Energy Prices
(with field usage)

Standard Electric Dryer

Design Options	UEC (kWh/yr)	Price (\$87)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	967	300.03	63.3	11.1	1209	920	683
1 Automatic Termination	851	313.01	55.7	9.8	1113	859	650
2 1 + Insulation	834	323.72	54.6	9.6	1108	859	654
3 2 + Recycle Exhaust	784	372.34	51.3	9.0	1110	875	683
4 2 + Microwave (1)	617	467.45	40.4	7.1	1048	863	712
5 2 + Heat Pump	292	695.31	19.1	3.4	970	883	811

Compact Electric Dryer (120V)

Design Options	UEC (kWh/yr)	Price (\$87)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	399	250.03	26.1	4.6	625	506	408
1 Automatic Termination	351	263.01	23.0	4.0	593	488	402
2 1 + Insulation	344	273.71	22.5	4.0	597	494	410
3 2 + Recycle Exhaust	323	322.33	21.2	3.7	627	530	451
4 2 + Microwave (1)	255	417.44	16.7	2.9	657	581	518
5 2 + Heat Pump	120	645.31	7.9	1.4	759	723	693

Compact Electric Dryer (240V)

Design Options	UEC (kWh/yr)	Price (\$87)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	431	280.03	28.2	5.0	685	556	451
1 Automatic Termination	379	293.01	24.8	4.4	650	536	443
2 1 + Insulation	372	303.71	24.3	4.3	653	542	451
3 2 + Recycle Exhaust	349	352.34	22.9	4.0	681	576	491
4 2 + Microwave (1)	275	447.44	18.0	3.2	706	624	557
5 2 + Heat Pump	130	675.31	8.5	1.5	798	759	727

Standard Gas Dryer

Design Options	UEC (MMBtu/yr)	Price (\$87)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	3.7280	340.03	19.7	3.7	623	533	459
1 Automatic Termination	3.2806	353.02	17.3	3.3	602	523	458
2 1 + Insulation	3.2150	363.72	17.0	3.2	607	530	467
3 2 + Recycle Exhaust	3.0221	412.34	16.0	3.0	641	569	509

Sensitivity Case 2: Low Regional Energy Prices
(with field usage)

Standard Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	<--- with Electric Water Heating			<---> with Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%	Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%
0 Baseline	716	300.03	59.0	9.4	952 784	34.0	5.3	676 579 488
1 Reduce Water Use	598	310.81	48.9	7.8	851 711	28.9	4.5	630 547 470
2 1 + Improv. Motor	585	317.14	48.1	7.7	848 711	28.0	4.4	627 547 472
3 2 + Booster Heater (1)	522	332.36	42.7	6.7	804 682	27.2	4.2	632 555 482
4 3 + Fill Control	510	345.03	41.7	6.6	805 686	26.6	4.1	638 563 492
5 1 + Booster Heater (2)	514	325.98	42.2	6.7	792 672	26.6	4.1	620 544 473
6 5 + Improv. Motor	501	332.27	41.3	6.5	789 671	25.8	4.0	617 544 475
7 6 + Fill Control	490	344.96	40.3	6.4	790 675	25.2	3.9	623 552 484

Standard Water Heating Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	<--- with Electric Water Heating			<---> with Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%	Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%
0 Baseline	636	320.03	52.3	8.2	897 749	32.9	5.1	683 589 502
1 Reduce Water Use	534	330.81	43.5	6.9	811 687	27.9	4.3	639 560 485
2 1 + Reduce Booster Use(1)	513	333.71	42.1	6.6	799 679	26.6	4.1	627 552 480
3 2 + Improv. Motor	500	339.90	41.3	6.5	796 678	25.7	3.9	624 551 482
4 3 + Fill Control	489	352.43	40.3	6.3	797 682	25.2	3.9	631 559 492

Compact Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	<--- with Electric Water Heating			<---> with Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%	Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%
0 Baseline	467	260.03	38.0	6.0	679 571	24.5	3.8	531 461 395
1 Reduce Water Use	397	270.80	31.9	5.1	623 532	21.1	3.3	504 444 387
2 1 + Reduce Booster Use(1)	383	273.71	30.9	4.9	615 527	20.2	3.1	497 439 385
3 2 + Improv. Motor	371	279.89	30.2	4.8	613 527	19.4	3.0	495 439 387
4 3 + Fill Control	363	292.43	29.5	4.7	618 534	19.1	3.0	503 449 398

dollars are in \$1987

1993 elec price (\$/MMBtu)	6.8731
1993 gas price (\$/MMBtu)	5.7305
water cost (\$/gal)	0.001957

Stock eff. elec WH	85.00%
Stock eff. gas WH	52.00%
elec WH/(elec&gas WH)	44.00%
gas WH/(elec&gas WH)	56.00%

Standard Clothes Washers 115V, Capacity 2.6 cu.ft.

Design Options	UEC (kWh/yr)	Price (\$87)	With Electric Water Heating			With Gas Water Heating						
			Annual MMBtu	Life Cycle Cost 2%	7%	Annual MMBtu	Life Cycle Cost 2%	7%				
0 Baseline 5 Settings	950	460.05	111.7	12.6	1820	1441	1101	64.7	6.7	1248	1028	831
1 Eliminate Warm/Warm Set.	746	460.05	92.7	9.9	1590	1275	992	57.1	5.4	1155	961	787
2 Eliminate Warm Rinse	674	460.05	86.0	8.9	1507	1215	953	54.3	4.9	1122	937	772
3 2 + Improv. Motor	660	482.92	84.9	8.8	1517	1229	970	53.2	4.8	1131	951	788
4 3 + Plastic Tub	657	497.23	84.6	8.7	1528	1240	983	53.1	4.7	1144	964	802
5 4 + Therm. Mix. Valve (1)	653	528.31	84.3	8.7	1555	1268	1012	53.0	4.7	1174	994	832
6 2 + Horizontal Axis	262	665.03	40.5	3.4	1159	1021	897	29.2	2.0	1020	921	832
7 6 + Plastic Tub	260	679.36	40.4	3.4	1171	1034	911	29.1	2.0	1034	935	846
7 7 + Therm. Mix. Valve (1)	259	710.45	40.3	3.4	1201	1064	942	29.1	2.0	1065	966	877

Compact Clothes Washers 115V, Capacity 1.45 cu.ft.

Design Options		UEC (kWh/yr)	Price (\$87)	With Electric Water Heating			With Gas Water Heating					
				Annual Cost	MMBtu /year	Life Cycle Cost 2%	7%	Annual Cost	MMBtu /year	Life Cycle Cost 2%	7%	
0	Baseline 5 Settings	688	356.53	77.8	9.1	1304	1040	803	44.9	5.0	904	751
1	Eliminate Warm/Warm Set.	546	356.53	64.6	7.2	1143	924	727	39.6	4.1	839	704
2	Eliminate Warm Rinse	495	356.53	59.8	6.5	1085	882	700	37.7	3.7	815	687
3	2 + Improv. Motor	482	379.42	58.8	6.4	1096	896	717	36.7	3.6	826	702
4	3 + Plastic Tub	480	393.71	58.6	6.3	1108	908	730	36.6	3.6	839	715
5	4 + Therm. Mix. Valve (1)	477	424.79	58.3	6.3	1135	937	759	36.5	3.5	869	745
6	2 + Horizontal Axis	146	561.52	22.6	1.9	837	760	691	16.3	1.1	760	655
7	6 + Plastic Tub	145	575.84	22.5	1.9	850	774	705	16.2	1.1	774	718
8	7 + Therm. Mix. Valve (1)	144	606.94	22.4	1.9	880	804	736	16.2	1.1	804	749

Sensitivity Case 3: High Equipment Prices
(with Field Usage)

Standard Electric Dryer

Design Options	UEC (kWh/yr)	Price (\$87)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	967	360.04	76.4	11.1	1457	1108	823
1 Automatic Termination	851	375.61	67.2	9.8	1341	1034	783
2 1 + Insulation	834	389.00	65.9	9.6	1335	1034	788
3 2 + Recycle Exhaust	784	461.93	61.9	9.0	1351	1068	837
4 2 + Microwave (1)	617	604.59	48.8	7.1	1305	1082	900
5 2 + Heat Pump	292	884.00	23.1	3.4	1215	1110	1024

Compact Electric Dryer (120V)

Design Options	UEC (kWh/yr)	Price (\$87)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	399	300.04	31.5	4.6	753	609	491
1 Automatic Termination	351	315.61	27.7	4.0	714	587	484
2 1 + Insulation	344	328.99	27.2	4.0	720	595	494
3 2 + Recycle Exhaust	323	401.92	25.6	3.7	769	652	557
4 2 + Microwave (1)	255	544.58	20.1	2.9	834	742	666
5 2 + Heat Pump	120	824.00	9.5	1.4	961	917	882

Compact Electric Dryer (240V)

Design Options	UEC (kWh/yr)	Price (\$87)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	431	336.04	34.1	5.0	825	670	542
1 Automatic Termination	379	351.61	30.0	4.4	782	645	533
2 1 + Insulation	372	364.99	29.4	4.3	787	653	543
3 2 + Recycle Exhaust	349	437.93	27.6	4.0	834	708	605
4 2 + Microwave (1)	275	580.58	21.7	3.2	893	793	712
5 2 + Heat Pump	130	860.00	10.3	1.5	1008	961	922

Standard Gas Dryer

Design Options	UEC (MMBtu/yr)	Price (\$87)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	3.7280	408.04	21.4	3.7	715	617	537
1 Automatic Termination	3.2806	423.62	18.8	3.3	694	608	537
2 1 + Insulation	3.2150	437.00	18.4	3.2	702	617	549
3 2 + Recycle Exhaust	3.0221	509.93	17.3	3.0	759	680	615

Sensitivity Case 3: High Equipment Prices
(with Field Usage)

Standard Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	<--- With Electric Water Heating			<---> With Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2%	Annual Cost	MMBtu /year	Life Cycle Cost 2%
0 Baseline	716	360.04	70.1	9.4	1134	935	37.5	5.3
1 Reduce Water Use	598	374.37	58.1	7.8	1016	850	32.0	4.5
2 1 + Improv. Motor	585	383.87	57.1	7.7	1014	852	31.0	4.4
3 2 + Booster Heater (1)	522	404.11	50.7	6.7	963	819	30.3	4.2
4 3 + Fill Control	510	423.12	49.4	6.6	969	828	29.7	4.1
5 1 + Booster Heater (2)	514	397.78	50.0	6.7	950	808	29.7	4.1
6 5 + Improv. Motor	501	407.21	49.0	6.5	948	809	28.7	4.0
7 6 + Fill Control	490	426.25	47.8	6.4	954	818	28.1	3.9

Standard Water Heating Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	<--- With Electric Water Heating			<---> With Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2%	Annual Cost	MMBtu /year	Life Cycle Cost 2%
0 Baseline	636	384.04	62.0	8.2	1069	892	36.6	5.1
1 Reduce Water Use	534	398.37	51.6	6.9	968	821	31.3	4.3
2 1 + Reduce Booster Use (1)	513	402.23	49.9	6.6	954	811	29.6	4.1
3 2 + Improv. Motor	500	411.52	48.9	6.5	952	813	28.6	3.9
4 3 + Fill Control	489	430.31	47.7	6.3	957	821	28.1	3.9

Compact Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	<--- With Electric Water Heating			<---> With Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2%	Annual Cost	MMBtu /year	Life Cycle Cost 2%
0 Baseline	467	312.04	45.1	6.0	809	681	27.5	3.8
1 Reduce Water Use	397	326.36	37.9	5.1	744	637	23.8	3.3
2 1 + Reduce Booster Use (1)	383	330.23	36.7	4.9	736	631	22.7	3.1
3 2 + Improv. Motor	371	339.50	35.8	4.8	735	633	21.8	3.0
4 3 + Fill Control	363	358.31	35.0	4.7	745	645	21.4	3.0

Sensitivity Case 4: High Regional Energy Prices
(with field usage)

dollars are in \$1987

Clothes Washer (cycle/yr)	380
Clothes Dryer (cycle/yr)	359
Dishwasher (cycle/yr)	229
1993 elec price (\$/MMBtu)	7.9080
1993 gas price (\$/MMBtu)	6.7575
water cost (\$/gal)	0.001957
Stock eff. elec WH	85.00%
Stock eff. gas WH	52.00%
elec WH/(elec&gas WH)	44.00%
gas WH/(elec&gas WH)	56.00%

Standard Clothes Washers 115V, Capacity 2.6 cu.ft.

Design Options	UEC (kWh/yr)	Price (\$87)	With Electric Water Heating			With Gas Water Heating		
			Annual MMBtu	Life Cycle Cost 2%	7%	Annual MMBtu	Life Cycle Cost 2%	7%
0 Baseline 5 Settings	950	400.04	124.7	12.6	1919	1496	1116	71.6
1 Eliminate Warm/Warm Set.	746	400.04	103.0	9.9	1654	1304	991	62.6
2 Eliminate Warm Rinse	674	400.04	95.2	8.9	1560	1236	946	59.4
3 2 + Improv. Motor	660	411.53	94.0	8.8	1556	1237	951	58.1
4 3 + Plastic Tub	657	421.07	93.6	8.7	1561	1243	958	58.0
5 4 + Therm. Mix. Valve (1)	653	441.79	93.2	8.7	1577	1260	977	57.8
6 2 + Horizontal Axis	262	570.86	44.1	3.4	1108	958	824	31.2
7 6 + Plastic Tub	260	580.41	43.9	3.4	1115	966	832	31.2
8 7 + Therm. Mix. Valve (1)	259	601.14	43.8	3.4	1135	986	852	31.1

Compact Clothes Washers 115V, Capacity 1.45 cu.ft.

Design Options	UEC (kWh/yr)	Price (\$87)	With Electric Water Heating			With Gas Water Heating		
			Annual MMBtu	Life Cycle Cost 2%	7%	Annual MMBtu	Life Cycle Cost 2%	7%
0 Baseline 5 Settings	688	310.03	87.2	9.1	1373	1076	811	50.1
1 Eliminate Warm/Warm Set.	546	310.03	72.0	7.2	1187	942	723	43.8
2 Eliminate Warm Rinse	495	310.03	66.6	6.5	1121	895	692	41.5
3 2 + Improv. Motor	482	321.53	65.4	6.4	1118	896	697	40.4
4 3 + Plastic Tub	480	331.06	65.2	6.3	1125	903	705	40.2
5 4 + Therm. Mix. Valve (1)	477	351.78	64.8	6.3	1142	921	724	40.1
6 2 + Horizontal Axis	146	480.85	24.6	1.9	780	697	622	17.4
7 6 + Plastic Tub	145	490.40	24.5	1.9	789	706	631	17.4
8 7 + Therm. Mix. Valve (1)	144	511.13	24.4	1.9	808	725	651	17.4

Sensitivity Case 4: High Regional Energy Prices
(with field usage)

Standard Electric Dryer

Design Options	UEC (kWh/yr)	Price (\$/7)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	967	300.03	87.9	11.1	1562	1161	832
1 Automatic Termination	851	313.01	77.4	9.8	1424	1071	781
2 1 + Insulation	834	323.72	75.8	9.6	1412	1066	783
3 2 + Recycle Exhaust	784	372.34	71.3	9.0	1396	1070	804
4 2 + Microwave (1)	617	467.45	56.1	7.1	1273	1017	807
5 2 + Heat Pump	292	695.31	26.5	3.4	1076	955	856

Compact Electric Dryer (120V)

Design Options	UEC (kWh/yr)	Price (\$/7)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	399	250.03	36.3	4.6	771	605	470
1 Automatic Termination	351	263.01	31.9	4.0	722	576	456
2 1 + Insulation	344	273.71	31.3	4.0	723	580	463
3 2 + Recycle Exhaust	323	322.33	29.4	3.7	745	610	500
4 2 + Microwave (1)	255	417.44	23.2	2.9	750	644	558
5 2 + Heat Pump	120	645.31	10.9	1.4	803	753	712

Compact Electric Dryer (240V)

Design Options	UEC (kWh/yr)	Price (\$/7)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	431	280.03	39.2	5.0	843	664	517
1 Automatic Termination	379	293.01	34.5	4.4	788	631	502
2 1 + Insulation	372	303.71	33.8	4.3	789	635	508
3 2 + Recycle Exhaust	349	352.34	31.8	4.0	808	663	545
4 2 + Microwave (1)	275	447.44	25.0	3.2	807	692	599
5 2 + Heat Pump	130	675.31	11.8	1.5	845	791	747

Standard Gas Dryer

Design Options	UEC (MMBtu/yr)	Price (\$/7)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	3.7280	340.03	25.2	3.7	702	587	493
1 Automatic Termination	3.2806	353.02	22.2	3.3	671	570	487
2 1 + Insulation	3.2150	363.72	21.7	3.2	676	576	495
3 2 + Recycle Exhaust	3.0221	412.34	20.4	3.0	706	612	536

Sensitivity Case 4: High Regional Energy Prices
(with field usage)

Standard Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	<--- With Electric Water Heating			---><--- With Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2%	Annual Cost	MMBtu /year	Life Cycle Cost 2%
0 Baseline	716	300.03	79.9	9.4	1182	741	42.9	774
1 Reduce Water Use	598	310.81	66.2	7.8	1042	676	36.6	715
2 1 + Improv. Motor	585	317.14	65.0	7.7	1035	676	35.5	709
3 2 + Booster Heater (1)	522	332.36	57.6	6.7	969	651	34.7	715
4 3 + Fill Control	510	345.03	56.2	6.6	966	655	33.9	720
5 1 + Booster Heater (2)	514	325.98	56.9	6.7	954	640	33.9	700
6 5 + Improv. Motor	501	332.27	55.7	6.5	948	640	32.8	694
7 6 + Fill Control	490	344.96	54.4	6.4	945	645	32.1	699

Standard Water Heating Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	<--- With Electric Water Heating			---><--- With Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2%	Annual Cost	MMBtu /year	Life Cycle Cost 2%
0 Baseline	636	320.03	70.5	8.2	1099	709	41.8	782
1 Reduce Water Use	534	330.81	58.7	6.9	979	655	35.8	726
2 1 + Reduce Booster Use(1)	513	333.71	56.8	6.6	961	647	33.9	708
3 2 + Improv. Motor	500	339.90	55.7	6.5	954	647	32.7	701
4 3 + Fill Control	489	352.43	54.3	6.3	952	652	32.0	706

Compact Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	<--- With Electric Water Heating			---><--- With Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2%	Annual Cost	MMBtu /year	Life Cycle Cost 2%
0 Baseline	467	260.03	51.3	6.0	826	543	31.4	607
1 Reduce Water Use	397	270.80	43.1	5.1	747	509	27.2	572
2 1 + Reduce Booster Use(1)	383	273.71	41.8	4.9	735	505	25.9	560
3 2 + Improv. Motor	371	279.89	40.8	4.8	730	505	24.9	555
4 3 + Fill Control	363	292.43	39.8	4.7	732	512	24.4	562

Sensitivity Case 5: Low Equipment Prices
(with field usage)

dollars are in \$1987

Clothes Washer (cycle/yr)	380
Clothes Dryer (cycle/yr)	359
Dishwasher (cycle/yr)	229
1993 elec price (\$/MMBtu)	6.8731
1993 gas price (\$/MMBtu)	5.7305
water cost (\$/gal)	0.001957
Stock eff. elec WH	85.00%
Stock eff. gas WH	52.00%
elec WH/(elec&gas WH)	44.00%
gas WH/(elec&gas WH)	56.00%

Standard Clothes Washers 115V, Capacity 2.6 cu.ft.

Design Options	UEC (kWh/yr)	Price (\$87)	<--- with Electric Water Heating			<---<---<--- with Gas Water Heating		
			Annual MMBtu	Life Cycle Cost 2%	7%	Annual MMBtu	Life Cycle Cost 2%	7%
0 Baseline 5 Settings	950	340.03	111.7	12.6	1700	1321	981	1128
1 Eliminate Warm/Warm Set.	746	340.03	92.7	9.9	1470	1155	872	1035
2 Eliminate Warm Rinse	674	340.03	86.0	8.9	1387	1095	833	1002
3 2 + Improv. Motor	660	340.14	84.9	8.8	1374	1086	827	989
4 3 + Plastic Tub	657	344.91	84.6	8.7	1375	1088	830	992
5 4 + Therm. Mix. Valve (1)	653	355.27	84.3	8.7	1382	1095	839	1001
6 2 + Horizontal Axis	262	476.69	40.5	3.4	970	832	709	832
7 6 + Plastic Tub	260	481.47	40.4	3.4	974	836	713	836
8 7 + Therm. Mix. Valve (1)	259	491.83	40.3	3.4	983	846	723	846

Compact Clothes Washers 115V, Capacity 1.45 cu.ft.

Design Options	UEC (kWh/yr)	Price (\$87)	<--- with Electric Water Heating			<---<---<--- with Gas Water Heating		
			Annual MMBtu	Life Cycle Cost 2%	7%	Annual MMBtu	Life Cycle Cost 2%	7%
0 Baseline 5 Settings	688	263.53	77.8	9.1	1211	947	710	811
1 Eliminate Warm/Warm Set.	546	263.53	64.6	7.2	1050	831	634	746
2 Eliminate Warm Rinse	495	263.53	59.8	6.5	992	789	607	722
3 2 + Improv. Motor	482	263.64	58.8	6.4	980	780	601	711
4 3 + Plastic Tub	480	268.41	58.6	6.3	982	783	605	714
5 4 + Therm. Mix. Valve (1)	477	278.77	58.3	6.3	989	791	613	723
6 2 + Horizontal Axis	146	400.18	22.6	1.9	675	599	530	598
7 6 + Plastic Tub	145	404.96	22.5	1.9	679	603	534	603
8 7 + Therm. Mix. Valve (1)	144	415.32	22.4	1.9	689	612	544	613

Sensitivity Case 5: Low Equipment Prices
(with field usage)

Standard Electric Dryer

Design Options	UEC (kWh/yr)	Price (\$87)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	967	240.02	76.4	11.1	1337	988	703
1 Automatic Termination	851	250.41	67.2	9.8	1216	909	658
2 1 + Insulation	834	258.44	65.9	9.6	1205	904	657
3 2 + Recycle Exhaust	784	282.75	61.9	9.0	1172	889	658
4 2 + Microwave (1)	617	330.31	48.8	7.1	1031	808	626
5 2 + Heat Pump	292	506.63	23.1	3.4	838	732	646

Compact Electric Dryer (120V)

Design Options	UEC (kWh/yr)	Price (\$87)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	399	200.02	31.5	4.6	653	509	391
1 Automatic Termination	351	210.41	27.7	4.0	609	482	378
2 1 + Insulation	344	218.43	27.2	4.0	609	485	383
3 2 + Recycle Exhaust	323	242.74	25.6	3.7	610	493	398
4 2 + Microwave (1)	255	290.30	20.1	2.9	579	487	412
5 2 + Heat Pump	120	466.63	9.5	1.4	603	560	524

Compact Electric Dryer (240V)

Design Options	UEC (kWh/yr)	Price (\$87)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	431	224.02	34.1	5.0	713	558	430
1 Automatic Termination	379	234.41	30.0	4.4	665	528	416
2 1 + Insulation	372	242.43	29.4	4.3	664	530	420
3 2 + Recycle Exhaust	349	266.75	27.6	4.0	663	537	434
4 2 + Microwave (1)	275	314.30	21.7	3.2	626	527	446
5 2 + Heat Pump	130	490.63	10.3	1.5	638	591	553

Standard Gas Dryer

Design Options	UEC (MMBtu/yr)	Price (\$87)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	3.7280	272.02	21.4	3.7	579	481	401
1 Automatic Termination	3.2806	282.42	18.8	3.3	552	467	396
2 1 + Insulation	3.2150	290.44	18.4	3.2	555	471	402
3 2 + Recycle Exhaust	3.0221	314.75	17.3	3.0	563	484	420

Sensitivity Case 5: Low Equipment Prices
(with field usage)

Standard Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	<--- With Electric Water Heating			<---> Annual			with Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2%	15%	Cost	MMBtu /year	Annual Cost	Life Cycle Cost 2%	15%
0 Baseline	716	240.02	70.1	9.4	1014	815	627	37.5	654	54	447
1 Reduce Water Use	598	247.25	58.1	7.8	889	723	568	32.0	600	509	424
2 1 + Improv. Motor	585	250.41	57.1	7.7	881	718	566	31.0	592	504	421
3 2 + Booster Heater (1)	522	260.61	50.7	6.7	820	676	540	30.3	596	509	428
4 3 + Fill Control	510	266.94	49.4	6.6	812	672	540	29.7	595	510	431
5 1 + Booster Heater (2)	514	254.18	50.0	6.7	806	664	530	29.7	582	497	418
6 5 + Improv. Motor	501	257.33	49.0	6.5	798	659	528	28.7	574	492	416
7 6 + Fill Control	490	263.67	47.8	6.4	791	655	528	28.1	574	494	419

Standard Water Heating Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	<--- With Electric Water Heating			<---> Annual			with Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2%	15%	Cost	MMBtu /year	Annual Cost	Life Cycle Cost 2%	15%
0 Baseline	636	256.02	62.0	8.2	941	764	598	36.6	661	556	458
1 Reduce Water Use	534	263.25	51.6	6.9	833	686	548	31.3	609	520	436
2 1 + Reduce Booster Use (1)	513	265.19	49.9	6.6	817	674	541	29.6	593	508	429
3 2 + Improv. Motor	500	268.28	48.9	6.5	809	669	538	28.6	585	503	426
4 3 + Fill Control	489	274.55	47.7	6.3	802	666	538	28.1	584	504	429

Compact Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	<--- With Electric Water Heating			<---> Annual			with Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2%	15%	Cost	MMBtu /year	Annual Cost	Life Cycle Cost 2%	15%
0 Baseline	467	208.02	45.1	6.0	705	577	457	27.5	512	433	360
1 Reduce Water Use	397	215.24	37.9	5.1	633	526	424	23.8	478	410	347
2 1 + Reduce Booster Use (1)	383	217.19	36.7	4.9	623	518	420	22.7	468	403	342
3 2 + Improv. Motor	371	220.28	35.8	4.8	616	514	418	21.8	461	399	341
4 3 + Fill Control	363	226.55	35.0	4.7	613	513	420	21.4	462	402	345

dollars are in \$1987

1993 elec price (\$/MMBtu)	7.9080
1993 gas price (\$/MMBtu)	6.7575
water cost (\$/gal)	0.001957

Stock eff. elec	WH	85.00%
Stock eff. gas	WH	52.00%
elec WH/(elec&gas	WH)	44.00%
gas WH/(elec&gas	WH)	56.00%

Design Options	UEC (kWh/yr)	Price (\$/Bt)	With Electric Water Heating			With Gas Water Heating						
			Annual Cost	MMBtu /year	Life Cycle Cost 2%	Annual Cost	MMBtu /year	Life Cycle Cost 2%				
0 Baseline 5 Settlings	950	340.03	124.7	12.6	1859	1436	1056	71.6	6.7	1213	969	751
1 Eliminate Warm/Warm Set.	746	340.03	103.0	9.9	1594	1244	931	62.6	5.4	1103	890	699
2 Eliminate Warm Rinse	674	340.03	95.2	8.9	1500	1176	886	59.4	4.9	1063	862	681
3 2 + Improv. Motor	660	340.14	94.0	8.8	1485	1165	879	58.1	4.8	1048	851	674
4 3 + Plastic Tub	657	344.91	93.6	8.7	1485	1167	882	58.0	4.7	1051	854	678
5 4 + Therm. Mix. Valve (1)	653	355.27	93.2	8.7	1491	1174	890	57.8	4.7	1060	863	687
6 2 + Horizontal Axis	262	476.69	44.1	3.4	1013	864	729	31.2	2.0	857	751	656
7 6 + Plastic Tub	260	481.47	43.9	3.4	1017	867	733	31.2	2.0	861	755	660
8 7 + Therm. Mix. Valve (1)	259	491.83	43.8	3.4	1025	876	743	31.1	2.0	871	765	670

Design Options	UEC (kwh/yr)	Price (\$87)	<--- With Electric Water Heating			--->X--- with Gas Water Heating					
			Annual MMBtu /year	Life Cycle Cost 2%	7%	Annual MMBtu /year	Life Cycle Cost 2%	7%			
0 Baseline 5 Settlings	688	263.53	87.2	9.1	1326	1030	764	50.1	873	703	551
1 Eliminate Warm/Warm Set.	546	263.53	72.0	7.2	1141	896	677	43.8	4.1	797	515
2 Eliminate Warm Rinse	495	263.53	66.6	6.5	1074	848	645	41.5	3.7	769	502
3 2 + Improv. Motor	482	263.64	65.4	6.4	1060	838	639	40.4	3.6	755	495
4 3 + Plastic Tub	480	268.41	65.2	6.3	1062	841	642	40.2	3.6	758	499
5 4 + Therm. Mix. Valve (1)	477	278.77	64.8	6.3	1069	848	651	40.1	3.5	767	509
6 2 + Horizontal Axis	146	400.18	24.6	1.9	699	616	541	17.4	1.1	612	500
7 6 + Plastic Tub	145	404.96	24.5	1.9	703	620	546	17.4	1.1	617	505
8 7 + Therm. Mix. Valve (1)	144	415.32	24.4	1.9	713	630	555	17.4	1.1	627	515

Sensitivity Case 6: High Regional Energy Prices and Low Equipment Prices
(with field usage)

Standard Electric Dryer

Design Options	UEC (kWh/yr)	Price (\$/7)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	967	240.02	87.9	11.1	1502	1101	772
1 Automatic Termination	851	250.41	77.4	9.8	1361	1008	719
2 1 + Insulation	834	258.44	75.8	9.6	1347	1001	717
3 2 + Recycle Exhaust	784	282.75	71.3	9.0	1306	981	714
4 2 + Microwave (1)	617	330.31	56.1	7.1	1136	880	670
5 2 + Heat Pump	292	506.63	26.5	3.4	888	766	667

Compact Electric Dryer (120V)

Design Options	UEC (kWh/yr)	Price (\$/7)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	399	200.02	36.3	4.6	721	555	420
1 Automatic Termination	351	210.41	31.9	4.0	669	523	404
2 1 + Insulation	344	218.43	31.3	4.0	668	525	408
3 2 + Recycle Exhaust	323	242.74	29.4	3.7	665	531	421
4 2 + Microwave (1)	255	290.30	23.2	2.9	623	517	430
5 2 + Heat Pump	120	466.63	10.9	1.4	624	574	533

Compact Electric Dryer (240V)

Design Options	UEC (kWh/yr)	Price (\$/7)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	431	224.02	39.2	5.0	787	608	461
1 Automatic Termination	379	234.41	34.5	4.4	730	572	443
2 1 + Insulation	372	242.43	33.8	4.3	728	573	447
3 2 + Recycle Exhaust	349	266.75	31.8	4.0	723	578	459
4 2 + Microwave (1)	275	314.30	25.0	3.2	673	559	466
5 2 + Heat Pump	130	490.63	11.8	1.5	660	606	562

Standard Gas Dryer

Design Options	UEC (MMBtu/yr)	Price (\$/7)	Annual Cost	MMBtu /year	Life Cycle Cost 2%	Life Cycle Cost 7%	Life Cycle Cost 15%
0 Baseline	3.7280	272.02	25.2	3.7	634	519	425
1 Automatic Termination	3.2806	282.42	22.2	3.3	601	500	417
2 1 + Insulation	3.2150	290.44	21.7	3.2	602	503	422
3 2 + Recycle Exhaust	3.0221	314.75	20.4	3.0	608	515	438

Sensitivity Case 6: High Regional Energy Prices and Low Equipment Prices
(with field usage)

Standard Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	<--- With Electric Water Heating			<---> With Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%	Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%
0 Baseline	716	240.02	79.9	9.4	1122	895	681	42.9 5.3 714 592 477
1 Reduce Water Use	598	247.25	66.2	7.8	978	790	613	36.6 4.5 652 548 450
2 1 + Improv. Motor	585	250.41	65.0	7.7	969	783	610	35.5 4.4 642 541 446
3 2 + Booster Heater (1)	522	260.61	57.6	6.7	897	733	579	34.7 4.2 643 545 452
4 3 + Fill Control	510	266.94	56.2	6.6	888	728	577	33.9 4.1 642 545 454
5 1 + Booster Heater (2)	514	254.18	56.9	6.7	882	720	568	33.9 4.1 629 532 441
6 5 + Improv. Motor	501	257.33	55.7	6.5	873	714	565	32.8 4.0 619 526 438
7 6 + Fill Control	490	263.67	54.4	6.4	864	709	564	32.1 3.9 618 527 441

Standard Water Heating Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	<--- With Electric Water Heating			<---> With Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%	Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%
0 Baseline	636	256.02	70.5	8.2	1035	834	645	41.8 5.1 718 599 487
1 Reduce Water Use	534	263.25	58.7	6.9	912	744	587	35.8 4.3 658 556 461
2 1 + Reduce Booster Use (1)	513	265.19	56.8	6.6	892	731	579	33.9 4.1 639 543 452
3 2 + Improv. Motor	500	268.28	55.7	6.5	883	724	576	32.7 3.9 629 536 449
4 3 + Fill Control	489	274.55	54.3	6.3	874	720	574	32.0 3.9 628 537 451

Compact Dishwasher 115V

Design Options	UEC (kWh/yr)	Price (\$87)	<--- With Electric Water Heating			<---> With Gas Water Heating		
			Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%	Annual Cost	MMBtu /year	Life Cycle Cost 2% 7% 15%
0 Baseline	467	208.02	51.3	6.0	774	628	491	31.4 3.8 555 466 382
1 Reduce Water Use	397	215.24	43.1	5.1	691	560	453	27.2 3.3 516 438 366
2 1 + Reduce Booster Use (1)	383	217.19	41.8	4.9	679	560	448	25.9 3.1 503 430 360
3 2 + Improv. Motor	371	220.28	40.8	4.8	670	554	445	24.9 3.0 495 424 358
4 3 + Fill Control	363	226.55	39.8	4.7	666	553	446	24.4 3.0 496 427 361

7. IMPACTS OF STANDARDS ON MANUFACTURERS

This chapter describes estimates of the impacts of standards on manufacturers of dishwashers, clothes washers, and clothes dryers. These estimates are based on the Lawrence Berkeley Laboratory Manufacturer Impact Model (LBL-MIM). The LBL-MIM collects into one spreadsheet all calculations necessary for determining the impact of a change in standards on an industry's profitability and level of production. The impact of any change in efficiency standards on appliance manufacturers depends on the interaction of three factors: the costs imposed by the change in standards, the price elasticity experienced by a single firm, and the two industry elasticities of demand. The LBL-MIM integrates and analyzes these three factors as they apply to a single firm. A complete description of LBL-MIM and the model inputs and outputs for each of the industries analyzed is included in Appendix C.

This chapter begins with a profile of the industries being analyzed. Next, an overview of the analysis is given, which discusses the goals of the impact analysis with some caveats about interpreting the results. The items discussed in the overview are long-run impacts, short-run impacts, impacts as a function of firm size, and sensitivity analysis. The final three sections describe the impacts of various standards levels on manufacturers of dishwashers, clothes washers, and clothes dryers, respectively.

7.1 INDUSTRY PROFILE

The Industry Profile looks first at demand-related characteristics. Housing starts and appliance saturation rates are listed, with the primary focus on annual unit shipments and dollar sales for each of the appliances: dishwashers, clothes washers, and clothes dryers. Supply-related characteristics are considered next. These include market concentration rates; labor and capital data, by industry grouping; import and export data; and a brief description of mergers and acquisitions in these industries. Next, consumer and producer price indexes are compared, and the profile ends with a look at two supply-demand balance characteristics: inventory levels and unfilled orders.

7.1.1 Demand

Units Shipped and Housing Starts

Figure 7.1 shows shows annual dishwasher, clothes washer, and clothes dryer shipments and housing starts between 1967 and 1986. There is a strong correlation between housing starts and sales of these appliances, which is seen clearly in the nearly exact parallel of the graphs in the figure. Although the changes in shipments of laundry products are not entirely the result of changes in new housing starts, housing starts can be used to predict shipments of these 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 the laundry products being analyzed can be attributed to the fluctuations in housing starts.

Laundry Product Shipments Compared to Housing Starts (Source: Current Industrial Reports)

Figure 7.1. Laundry Product Shipments Compared to 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. In general, for these two reasons, there is a strong correlation between new housing starts and all appliance shipments.

Other factors such as age of the current stock of appliances, purchase price, fuel costs, consumer income, and climate conditions, have varying degrees of importance in determining shipments of the various appliances covered by the National Appliance Energy Conservation Act of 1987 (NAECA). 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.

Sales in Nominal and Constant Dollars

Figures 7.2 to 7.4 show the units shipped, nominal dollar sales, and constant dollar sales for each of the products being analyzed. Increases and decreases in dishwasher, clothes washer, and clothes dryer shipments tend to correspond to business cycles in the national economy. Shipments of these laundry products hit low points in both the 1974-75 recession and the 1982 recession, and record or near-record highs in the expansion years of 1972-73, 1979, and 1984-86. Note that constant dollar sales of clothes washers and clothes dryers have been gradually decreasing over time while shipments have gradually increased, reflecting the decreasing real price of these appliances. Constant dollar sales of dishwashers have stayed within a relatively constant band (when annual variations are accounted for), but shipments have increased greatly during the time period analyzed, also reflecting the decreasing real price of dishwashers. Prices are discussed more thoroughly in section 7.1.3.

Appliance Saturation Rates

The percentage of houses that own a particular appliance is called its saturation rate. Table 7.1 lists the saturation rates for the three analyzed appliances in selected years during the past 25 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, it is expected 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 clothes washers and clothes dryers.

Table 7.1. Appliance Saturation Rates
Percentage of Households Possessing the Product*

Product	1963	1973	1978	1983	1985
Dishwashers	9.0%	34.3%	41.9%	45.0%	47.5%
Clothes Washers	64.5	67.8	68.9	73.6	70.0
Clothes Dryers, Electric	NA	41.0	45.1	49.0	50.0
Clothes Dryers, Gas	NA	8.0	12.1	15.0	16.0

* These figures indicate the share of households that have at least one appliance of a particular type. The figures do not provide any indication of the extent to which some households may have more than one of the appliance.

Source: *Appliance*

Annual Dishwasher Shipments

(Source: Current Industrial Reports, Dept. of Commerce)

Figure 7.2. Annual Dishwasher Shipments

Annual Clothes Washer Shipments

(Source: Current Industrial Reports, Dept. of Commerce)

Figure 7.3. Annual Clothes Washer Shipments

Annual Clothes Dryer Shipments

(Source: Current Industrial Reports, Dept. of Commerce)

Figure 7.4. Annual Clothes Dryer Shipments

7.1.2 Supply

Market concentration

Market concentration is the extent to which market share is controlled by the largest firms in an industry. Table 7.2 shows the market concentration for the products according to the degree of the market controlled by the two, four, and five largest producers.

Market concentration is almost identical for the four products. All of the products show a high level of market concentration, with 93% of the market for each of the products being controlled by the top four producers. 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 power* 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 7.2. Percent of Market Controlled by the
Largest Producers of Each Product
(Market Shares in 1987)

Product	Number of Companies		
	Top Two	Top Four	Top Five
Dishwashers	67	93	99
Clothes Washers	67	93	97
Clothes Dryers, Electric	68	93	96
Clothes Dryers, Gas	68	93	96

Source: Appliance Manufacturer magazine

Figures 7.5 to 7.8 give a picture of the manufacturer market shares for dishwashers, clothes washers, and clothes dryers. Each of these products are made by a few manufacturers, most of which have large market shares. Note that in the dishwasher market, D&M is owned by WCI, and that in the clothes washer and dryer markets, Norge is owned by Maytag. The figures in Table 7.2 reflect this situation, i.e., their market shares are combined. combined).

Labor

Data in this section on labor and data in the following section on capital are categorized by Standard Industrial Code (SIC) grouping. Clothes washers and clothes dryers make up all of the Household Laundry Equipment grouping (SIC 3633). Dishwashers are part of the catch-all appliance product grouping Household Appliances Not Elsewhere Classified (N.E.C.) (SIC 3639). Dishwashers currently account for approximately 35% of the dollar value of shipments in the Household Appliances, N.E.C. category.

* Market 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, demand will not fall to zero, and if price is lowered by some small amount, demand will not become essentially infinite.

Dishwasher Market Shares - 1987

(Source: Appliance Manufacturer)

Figure 7.5. Dishwasher Market Shares

Clothes Washer Market Shares - 1987

(Source: *Appliance Manufacturer*)

Figure 7.6. Clothes Washer Market Shares

Electric Dryer Market Shares - 1987

(Source: Appliance Manufacturer)

Figure 7.7. Electric Dryer Market Shares

Gas Dryer Market Shares - 1987

(Source: Appliance Manufacturer)

Figure 7.8. Gas Dryer Market Shares

Table 7.3 shows the value added per production worker per hour, in constant 1982 dollars. Estimates are provided for SIC 3633, the household laundry equipment industry, and SIC 3639, the household appliance industry. The value added measure is an indication of the productivity of labor. The value added per production worker per hour has remained relatively constant during the time period analyzed for the industries under consideration.

Table 7.3. Value Added/Worker/Hour (Constant 1982 Dollars)

	Industry (SIC Code)	
	Household Laundry Equipment (3633)	Household Appliances, N.E.C. (3639)
1963	\$37.90	\$31.67
1967	33.73	29.42
1972	39.89	35.12
1977	42.67	31.26
1982	42.06	31.05
1985	45.52	34.23

Sources: 1977 and 1982 Census of Manufacturers and 1985 Annual Survey of Manufacturers, U.S. Department of Commerce

However, value added per production worker does not tell the whole story of labor productivity. There has been a steady decline in the real price of the appliances being analyzed (see section 7.1.3 on prices), with the result that labor may have improved its productivity regarding physical units produced. The value added measure has remained constant as a consequence of the decline (in real terms) of the dollar value per unit. This truth is borne out in Figures 7.9 and 7.10, which show an increase in units produced per worker per hour during the past 15 to 20 years in the industries analyzed. These figures also chart the number of production workers employed in the respective industries. The household laundry equipment grouping (SIC 3633) in particular shows both a clear downward trend in production workers employed and an upward trend in units produced per worker per hour, indicating an increase in productivity in this industry.

Capital

Table 7.4 shows the capital intensity over time for each of the industries being analyzed. Capital intensity is measured by the amount of gross capital stock per production worker, using constant 1982 dollars. The Household Laundry Equipment industry grouping shows a decrease in capital intensity from 1977 to 1982 and a leveling out thereafter. The Household Appliances, N.E.C. grouping, of which dishwashers are a part, shows an increase from 1977 to 1982, and then a leveling out.

Workers and Productivity - Household Laundry Equipment (SIC 3633)

Number of Production Workers and Units Produced per Worker per Hour

(Sources: 1977 and 1982 Census of Manufacturers, Annual Survey of Manufacturers and Current Industrial Reports, Dept. of Commerce)

Figure 7.9. Workers and Productivity - Household Laundry Equipment (SIC 3633)

Workers and Productivity - Household Appliances N.E.C. (SIC 3639)
Number of Production Workers and Units Produced per Worker per Hour
 (Sources: 1977 and 1982 Census of Manufacturers, Annual Survey of
 Manufacturers and Current Industrial Reports, Dept. of Commerce)

Figure 7.10. Workers and Productivity - Household Appliances N.E.C. (SIC 3639)

Table 7.4. Capital Intensity Gross Capital
Stock per Production Worker
(Constant 1982 Dollars)

Industry (SIC Code)	1977	1982	1985
Household Laundry Equipment (3633)	\$40,467	\$35,455	\$36,267
Household Appliances N.E.C. (3639)	26,996*	33,175	33,707

* This figure is for 1976; 1977 data were unavailable.

Sources: 1977 and 1982 Census of Manufacturers and 1985 Annual Survey of Manufacturers, U.S. Department of Commerce

Imports and Exports

Imports and exports are not significant factors in the sales of the appliances being analyzed. Figure 7.11 shows dishwasher exports as a percentage of manufacturer shipments and sales from 1969 to 1986. There are very few dishwashers imports, so imports are not shown on Figure 7.11. Dishwasher manufacturers have never experienced a large demand for exports, although exports were 8% of sales in 1974-75.

Figure 7.12 shows clothes washer imports and exports as a percentage of manufacturer shipments and sales from 1977 to 1986, the time period for which data are available. As the figure shows, exports have gradually decreased during this time period; imports increased sharply in 1985-86 although the increase was from negligible levels.

Figure 7.13 shows clothes dryer exports as a percentage of manufacturer shipments and sales from 1977 to 1986, the time period for which data are available. Clothes dryer exports have fluctuated between 1% and 2% of sales during this time period. Clothes dryer imports were negligible until 1986 and, thus, do not appear on the clothes dryer import/export graph. In 1986, clothes dryer imports reached 2% of units purchased in the United States and 1% of the dollar value.

Mergers and Acquisitions

The appliance manufacturing industry has a history of consolidation that is continuing. 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 also for offering 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 7.5 is a partial list of major acquisitions of appliance manufacturers covered in this analysis.

Exports of Dishwashers

(Source: *Current Industrial Reports*, Dept. of Commerce)

Figure 7.11. Dishwasher Exports

Imports and Exports of Clothes Washers

(Source: Current Industrial Reports, Dept. of Commerce)

Figure 7.12. Clothes Washer Imports and Exports

Exports of Clothes Dryers

(Source: Current Industrial Reports, Dept. of Commerce)

Figure 7.13. Clothes Dryer Exports

Table 7.5. Acquisitions of Appliance Manufacturers

Buyer	Purchase	Year
Whirlpool	Heil-Quaker Corp.	1964
Raytheon Co.	Amana Refrigeration, Inc.	1965
White Consolidated Ind.	Gibson Div. (Hupp Co.)	1966
Raytheon Co.	Caloric Corp.	1967
White Consolidated Ind.	Franklin Appliance Div. (Studebaker Corp.)	
White Consolidated Ind.	Kelvinator Appliance Div. (American Motor Corp.)	1968
Emerson Electric Co.	In-Sink-Erator	
Magic Chef, Inc.	Gaffers & Sattler	
Magic Chef, Inc.	Dixie-Narco, Inc.	
Magic Chef, Inc.	Johnson Corp.	1971
AB Electrolux (Sweden)	Eureka	1974
Rockwell International	Admiral Co.	
White Consolidated Ind.	Westinghouse Elec. Corp.'s Major Appliance Operations	1975
Caloric Corp. (Raytheon)	Glenwood Range Co.	1978
White Consolidated Ind.	Philco Appliance Business (Ford Motor Co.)	1979
White Consolidated Ind.	Frigidaire Appliance Business (General Motor Corp.)	
Magic Chef, Inc.	Admiral Div. (Rockwell)	
Magic Chef, Inc.	Norge	
Carrier	Jenn-Air	
Raytheon	Modern Maid Co.	
Raytheon	Speed Queen (McGraw Edison)	
United Technologies	Carrier	
AB Electrolux (Sweden)	Tappan	1981
Dart & Kraft	Hobart Corp.	
Magic Chef Inc.	Revco	
Maytag	Hardwick Stove	
Maytag	Jenn-Air (Carrier/United Techn.)	1982
Hobart (Dart & Kraft)	Chambers Corp. (Rangaire Corp.)	1983
Magic Chef, Inc.	Toastmaster	
Admiral (Magic Chef)	Warwick Manuf. Co.	1985
Chicago Pacific Corp.	The Hoover Co.	
Masco Corp.	Thermador-WasteKing (NI Ind.)	
AB Electrolux (Sweden)	White Consolidated Ind.	1986
Maytag Co.	Magic Chef, Inc.	
Chicago Pacific Corp.	Rowenta Group (West Germany) (Allegheny Int'l and Rothmans Deutschland GmbH)	
Whirlpool	Kitchen-Aid Division (Dart & Kraft, Inc.)	1986
GE	RCA	

Inter-City Gas Corp. (Canada)	Heil-Quaker Home Systems, Inc. (Whirlpool)	
Emerson Electric Co.	Whirlpool's Kitchen-Aid dishwashing manufacturing facility	
White Consolidated Ind.	Design & Manufacturing Corp.	1987
Thomas S.A. (France)	GE/RCA consumer electronics	
Toastmaster Div.	Management team buys division from Maytag Corp.	
Speed-Queen	Holiday-Hammond	
Whirlpool Corp.	Roper Corp.'s brand name	1988
GE	Roper Corp.'s physical assets including manufacturing facilities	
Maytag Corp.	Merger with Chicago Pacific Corp.	

Source: Various newspaper and magazine articles and industry reports.

7.1.3 Prices

Appliance prices have uniformly risen more slowly than aggregate indexes measuring consumer and producer prices. 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 7.14 shows, for the years 1966 to 1985, the CPI, the Producer Price Index (PPI) for all commodities, and the PPI for household appliances. The PPI for household appliances increases about half as much as the CPI and PPI for all commodities.

Figure 7.15 shows the "real" PPI for three different product groupings. This PPI for each product grouping is defined as the PPI for that product grouping, holding the overall PPI constant at 1967 = 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. by keeping inventories low.

Table 7.6 shows the month-by-month ratio of inventory to shipments for the years 1978 to 1984. Data are shown for the household appliances industry grouping and for the aggregate of all manufacturing industries. Appliance manufacturers moved from having an inventory ratio higher than the industry average in the late 1970s to one lower than the industry average in 1983 and 1984.

Consumer and Producer Price Indexes

(Sources: 1987 Economic Report of the President and 1987 Major Appliance Industry Facts Book, Association of Home Appliance Manufacturers)

Figure 7.14. Consumer and Producer Price Indexes

Real Producer Price Index by Product Grouping Appliance Product PPI adjusted by PPI for all commodities; 1967 = 100

(Sources: *Statistical Abstract of the U.S.* and *1987 Major Appliance Industry Facts Book*, Association of Home Appliance Manufacturers)

Figure 7.15. Real Producer Price Indexes

7.1.4 Supply-Demand Balance

Inventories

Firms manage inventories according to current needs and perceptions about future demand. They balance the need for keeping enough inventory on hand to meet present and expected future demand with the need for minimizing costs

Unfilled orders

The dollar level of unfilled orders is an indicator of excess or reduced demand. Generally the level of unfilled orders rises when there is excess demand and decreases with little demand. The ratio of unfilled orders to shipments is an indication of an industry's ability to keep a balance between supply and demand. This ratio will be different for different industries, but each industry will have a characteristic ratio range.

Table 7.7 shows the monthly unfilled orders-to-shipments ratio for the years 1978 to 1984. Data are shown for the household appliances industry grouping and for the aggregate of all manufacturing industries. Manufacturers of household appliances maintained a relatively constant unfilled orders ratio during this time period until 1983 and 1984, when the ratio dropped approximately 25%. These lower ratios are a result of increased shipments rather than decreased numbers of unfilled orders. Note that the unfilled orders ratios for both of the industry groupings are far below the average ratio for all manufacturing industries.

7.2 IMPACT ANALYSIS: AN OVERVIEW

This 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 three industries.

Section 7.2.1 discusses the meaning of long-run impacts and how they are analyzed. These impacts are most important simply because they will either persist or be so severe as to cause a restructuring of the industry. Section 7.2.2 discusses the meaning and analysis of short-run impacts. Section 7.2.3 describes the various types of sensitivity analysis performed on the model's results. 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. Sections 7.3 through 7.5 run parallel to section 7.2. These analyze the three industries in turn.

7.2.1 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.

Table 7.6 Inventory to Shipments Ratio — Seasonally Adjusted

ALL MANUFACTURING INDUSTRIES							
YEAR	1978	1979	1980	1981	1982	1983	1984
MONTH							
JAN	1.63	1.55	1.58	1.61	1.77	1.65	1.42
FEB	1.60	1.57	1.59	1.61	1.74	1.65	1.42
MAR	1.60	1.52	1.64	1.62	1.75	1.60	1.43
APR	1.55	1.60	1.71	1.60	1.75	1.58	1.44
MAY	1.57	1.53	1.76	1.62	1.71	1.55	1.46
JUN	1.57	1.58	1.77	1.61	1.71	1.51	1.46
JUL	1.59	1.56	1.74	1.62	1.70	1.51	1.47
AUG	1.57	1.59	1.72	1.63	1.72	1.49	1.48
SEP	1.57	1.59	1.66	1.67	1.70	1.46	1.50
OCT	1.55	1.59	1.61	1.69	1.74	1.46	1.49
NOV	1.55	1.61	1.60	1.72	1.72	1.43	1.48
DEC	1.55	1.61	1.61	1.74	1.71	1.40	1.46

HOUSEHOLD APPLIANCES							
YEAR	1978	1979	1980	1981	1982	1983	1984
MONTH							
JAN	1.88	1.84	1.45	1.53	1.86	1.43	1.18
FEB	1.91	1.82	1.57	1.57	1.82	1.55	1.30
MAR	1.80	1.79	1.61	1.62	1.78	1.51	1.28
APR	1.72	1.74	1.81	1.56	1.79	1.49	1.34
MAY	1.85	1.62	1.80	1.59	1.79	1.44	1.22
JUN	1.81	1.65	1.80	1.52	1.78	1.46	1.11
JUL	1.99	1.63	1.78	1.61	1.78	1.42	1.19
AUG	1.85	1.64	1.69	1.69	1.70	1.39	1.23
SEP	1.87	1.66	1.65	1.64	1.74	1.38	1.23
OCT	1.87	1.61	1.55	1.75	1.72	1.36	1.24
NOV	1.90	1.62	1.55	1.70	1.69	1.35	1.28
DEC	1.86	1.54	1.59	1.82	1.75	1.39	1.18

SOURCE: CURRENT INDUSTRIAL REPORTS, U. S. DEPARTMENT OF COMMERCE

Table 7.7 Unfilled Orders to Shipments Ratio — Seasonally Adjusted

ALL MANUFACTURING INDUSTRIES							
YEAR	1978	1979	1980	1981	1982	1983	1984
MONTH							
JAN	3.38	3.63	3.73	3.77	3.85	3.67	3.48
FEB	3.33	3.74	3.77	3.75	3.76	3.70	3.51
MAR	3.38	3.67	3.86	3.70	3.75	3.61	3.57
APR	3.30	3.90	3.94	3.66	3.81	3.61	3.59
MAY	3.41	3.71	4.00	3.68	3.72	3.59	3.57
JUN	3.43	3.83	4.03	3.66	3.73	3.52	3.53
JUL	3.47	3.78	3.97	3.67	3.71	3.56	3.58
AUG	3.43	3.79	4.01	3.66	3.72	3.55	3.55
SEP	3.50	3.86	3.83	3.70	3.68	3.51	3.55
OCT	3.54	3.80	3.79	3.73	3.78	3.52	3.46
NOV	3.59	3.87	3.77	3.73	3.78	3.52	3.46
DEC	3.59	3.88	3.81	3.77	3.76	3.38	3.36

HOUSEHOLD APPLIANCES							
YEAR	1978	1979	1980	1981	1982	1983	1984
MONTH							
JAN	0.44	0.43	0.34	0.36	0.44	0.34	0.28
FEB	0.45	0.43	0.37	0.37	0.43	0.37	0.31
MAR	0.42	0.42	0.38	0.38	0.42	0.36	0.30
APR	0.41	0.41	0.43	0.37	0.42	0.35	0.32
MAY	0.44	0.38	0.42	0.37	0.42	0.34	0.29
JUN	0.43	0.39	0.43	0.36	0.42	0.35	0.26
JUL	0.47	0.38	0.42	0.38	0.42	0.33	0.28
AUG	0.44	0.39	0.40	0.40	0.40	0.33	0.29
SEP	0.44	0.39	0.39	0.39	0.41	0.33	0.29
OCT	0.44	0.38	0.37	0.41	0.41	0.32	0.29
NOV	0.45	0.38	0.37	0.40	0.40	0.32	0.30
DEC	0.44	0.36	0.37	0.43	0.41	0.33	0.28

SOURCE: CURRENT INDUSTRIAL REPORTS, U.S. DEPARTMENT OF COMMERCE

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 for a more detailed discussion of the long run.

The fraction of increased cost of production (caused by more stringent standards) that manufacturers are able to pass on is determined by the nature of the cost, fixed or variable, and the elasticities of demand as seen by the price-setting firm. Once the price increase has been determined, this and the operating cost decrease (obtained from engineering data) are used with the elasticities of demand to determine the change in sales. These mechanisms are presented in Figure 7.16, which displays the most basic economic forces analyzed by the LBL-MIM.

As shown in Figure 7.16, the two cost changes do not translate directly into price changes. Instead, the reduction in operating cost makes the appliance more desirable, thereby shifting the demand curve out; an increase in production costs changes the marginal cost curve. Together these determine price and 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).

Figure 7.16. How Standards Cause a Change in ROE

The LBL-MIM simulates standards as follows. For each appliance, 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 cost used in Figure 7.16, and the energy usage determines the operating cost. MIM 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 cost. This change in markup can have an important impact on ROE. If the industry operating cost elasticity (ICE) is small, the changes in markup are small. If ICE is large, the changes in markup are relatively large.

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 TSD 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 standards levels. In these cases the manufacturer price is calculated from the economic markup*, which, as described above, is dependent on elasticities and price and operating cost 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 say (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 say that the chance of profits declining by more than 2% is only 2.3%.

7.2.2 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.

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 indirectly 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.

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

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 cycle of 18 years have been analyzed to determine the ratio between the decline in demand (industry-wide) and the induced decline in price. For dishwashers, a 10% change in demand caused price to change by about 0.3% in the same direction.

If the long-run prediction is for a decline in demand of 2%, for example, 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 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 than 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 appliance is growing. These factors are discussed in the sections on individual appliances.

7.2.3 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 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.

Note that for CC.L and dVC.L the change of one standard error from the the "Value" column to the "Changed" column 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.

Table 7.8. Sample Sensitivity Chart
Charts of Sensitivity and Profit for Dishwashers
Sensitivity of ROE to 1 S.E. change in Control Variable

Scenario-Primary Control Variables			Possible Standards Levels (Percent)				
Name	Value	Changed	1	2	3	4	5
IPE	-0.500	-0.772	0.04	0.03	-0.12	-0.10	-0.32
ICE	-0.125	-0.229	-0.07	-0.08	-0.16	-0.16	-0.28
ECC	0.068	0.075	-0.00	-0.00	-0.01	-0.01	-0.01
EP	0.000	0.010	-0.02	-0.03	-0.04	-0.05	-0.02
FCA	0.100	0.154	0.02	0.02	0.09	0.08	0.24
F1X	0.150	0.247	-0.05	-0.11	-0.21	-0.24	-0.24
CC.L	2.815	3.419	-0.02	-0.04	-0.07	-0.07	-0.09
dVC.L	4.770	5.793	0.04	0.04	0.08	0.08	0.14

Table 7.8 lists the sensitivities of ROE to the control panel inputs defined below:

1. IPE is the industry price elasticity;
2. ICE is the industry operating cost elasticity;
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.L is the estimate of one-time capital costs induced by standards;
8. dVC.L is the increase in variable costs necessary to reach a standards level.

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 a 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 figure out 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 up to 400 times. 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. This does not mean they are absolutely reliable, however, 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.

7.3 IMPACTS ON THE MANUFACTURERS OF DISHWASHERS

There have been several changes in MIM since the writing of *Technical support document (TSD): Energy conservation standards for consumer products: dishwashers, clothes washers, and clothes dryers* (DOE/CE-0267, July 1989). The primary changes which affect the analysis are the following:

1. Two programming bugs in the LBL-MIM spreadsheet were fixed. The first was to correct the passing through of capital costs in the calculation of retail prices which had overestimated the prices of some designs. The second was the revision of the short run calculation formulas to fully agree with the formulas for the long run calculations which had underestimated the short-run impact of several variables;

2. Engineering data has been revised and updated. New design options have been added and others dropped. In addition, the baseline cost of one product class has been revised to reflect current information.

Dishwashers were analyzed at trial standards levels 1 through 5 and for the base case. For a complete description of these levels, see Chapter 5.

7.3.1 Long-Run Impacts

The analysis shows that compared to the 1996 base case, at all trial standards levels, the clothes washer industry is likely to experience a ROE decrease. At standards level 1 for dishwashers, there is approximately a 74% chance that ROE will decrease, and that the expected decrease is 0.12%. At standards level 2 there is approximately a 77% chance of a decrease in ROE with an expected decrease of 0.18%. At standards level 3 there is approximately a 85% chance of an decrease in ROE with an expected decrease of 0.32%. At standards level 4 there is approximately a 74% chance of an decrease in ROE with an expected decrease of 0.26%. At standards level 5 there is approximately a 52% chance of an decrease in ROE with an expected decrease of 0.03%. These results are based on Table 7.9. The probabilities of change are computed from the expected change, the standard error of this estimate, and the assumption of a normal distribution.

The Manufacturer Impact Analysis assumes that manufacturers will meet the standards by increasing efficiency while maintaining the existing level of cleaning performance. This approach may overstate the impact of standards because the current test procedure does not include a cleaning performance measure. If manufacturers choose to degrade performance, they can meet the standards with essentially no changes in design. However, any manufacturer who chooses this route would find it profitable for only a short time because of its adverse impact on product acceptance. Industry consultants have estimated that this strategy would be viable for three to four years, at most.

Qualitative analysis

According to reports from within the industry, dishwasher manufacturing is characterized by economies of scale; which will tend to increase profit by making dishwashers more attractive and thereby increasing demand. However, this effect is smaller for dishwashers than for most other appliances. Also, the demand function is specified as a function of purchase price and operating cost, i.e., life-cycle cost under constant life-cycle cost elasticity. Therefore, as price changes, so does price elasticity, and consequently, markup. For instance, as prices increases, price elasticity increases, and markup decreases. The model calculates that these effects, when combined, are more likely to reduce economic profits than increase them at all standards levels, particularly at standards level 4.

Quantitative analysis

Table 7.9 referred to as the long-run output table, summarizes all essential outputs from the LBL-MIM simulations using the primary scenario for dishwashers. Four other scenarios are summarized and discussed in the sensitivity section, 7.3.4.

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

7.3.2 Short-Run Impacts

The business cycle presents the dishwasher manufacturing industry with fairly sharp periodic fluctuations in demand, much larger than the fluctuations predicted for any of the standards levels. These normal demand fluctuations present the same types of opportunities for price competition that will accompany fluctuations resulting from a change in standards. Regressing price on demand and a time trend for the past 18 years shows that a 10% fall in demand typically leads to a 0.3% fall in the price of dishwashers; a 10% demand increase has the reverse effect. This effect is taken into account as described in Section 7.2.2 and is used to produce a short-run version of the output table that is displayed in Table 7.10. Note that at each standards level analyzed for the dishwasher manufacturing industry, the short run ROE results are generally lower than the long-run results. For reasons that are explained in 7.2.2, the short-run change has been overestimated. Thus, the value for change in Table 7.10 should be viewed as somewhat too large in absolute value. The short-run impact on profit is also illustrated in the Monte Carlo module.

7.3.3 Impact as a Function of Firm Size

Firms in this industry may be divided into two groups: those that compete on large, sales volume products and those that compete in small, specialized markets. Small firms are generally forced to specialize in small market niches that offer some protection from the cost advantage that large firms hold when they can produce in volume. This effect can even be observed among the major producers in the tendency of the smaller major producers to make somewhat more specialized products.

First, consider differences among the major firms. As learned from discussions with industry consultants, average cost decreases with firm size (1). Thus, the industry has economies of scale, and large firms (to the extent that their facilities are up-to-date) have lower average costs than small firms. This fact, coupled with the increasing competitiveness of the national market, probably accounts for the continuing consolidation that has been occurring for several decades. The fact that the consolidation has been producing larger firms strongly corroborates the finding that large firms have a cost advantage.

Table 7.9. Dishwasher Output Table: Primary Scenario

Output Table - Dishwasher Scenario-Primary	Long Run					
	1996 Base	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in MIL)	0.70	0.70	0.70	0.70	0.69	0.68
Change (%)		0.23	0.15	-0.00	-0.79	-2.43
S.E. (%)		1.14	1.23	1.44	2.17	2.88
Price(\$)	215.20	218.74	219.54	221.56	226.71	234.96
Change (%)		1.64	2.02	2.95	5.35	9.18
S.E. (%)		0.48	0.54	0.74	1.11	1.88
Revenue (in \$M)	150.48	153.32	153.74	154.92	157.28	160.30
Change (%)		1.88	2.17	2.95	4.51	6.53
S.E. (%)		1.02	1.10	1.27	2.01	2.78
Net Income (in \$M)	2.41	2.41	2.41	2.42	2.44	2.49
Change (%)		-0.24	-0.03	0.34	1.29	3.27
S.E. (%)		2.76	3.85	4.88	6.30	9.30
ROE (%)	6.77	6.65	6.59	6.45	6.51	6.74
Difference		-0.12	-0.18	-0.32	-0.26	-0.03
S.E. (%)		0.19	0.24	0.31	0.41	0.58

Table 7.10. Dishwasher: Primary Scenario
Short-Run Output Table

Output Table Dishwasher Scenario-Primary	Short Run					
	1996 Base	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in MIL)	0.70	0.70	0.70	0.70	0.69	0.68
Change (%)	0.23	0.15	-0.00	-0.00	-0.78	-2.38
Price(\$)	215.20	218.75	219.55	221.55	226.64	234.76
Change (%)		1.65	2.02	2.95	5.32	9.09
Revenue (in \$M)	150.48	153.32	153.75	154.92	157.25	160.25
Change (%)		1.89	2.17	2.95	4.51	6.49
Net Income (in \$M)	2.41	2.41	2.41	2.42	2.43	2.46
Change (%)		-0.16	-0.00	0.27	0.72	1.73
ROE (%)	6.77	6.66	6.59	6.44	6.76	6.64
Difference (%)		-0.11	-0.18	-0.33	-0.30	-0.13
S.E. (%)		0.28	0.22	0.29	0.39	0.56

A principal implication of consolidation is that the smaller of the major firms will be, on average, in more danger of failing or being bought out than will the larger firms. Because of the greater precariousness of smaller firms, any decrease in average profitability is more likely to seriously damage a smaller firm, and an increase in average profitability is more likely to mean the difference between success and failure for a smaller firm.

From the point of view of competitiveness, a decrease in average profitability could speed up the process of consolidation, producing a less competitive industry, and an increase in average profitability could help maintain the current level of competition. Either effect might well be temporary because in the long run the number of firms should be determined by the industry's cost structure and by the way a single firm's elasticity of demand relates to the number of competing firms.

Although larger firms have a cost advantage because of economies of scale, the very small firms in the dishwasher manufacturing industry have found market niches in which to survive profitably. The small firms sell dishwashers primarily to the replacement and kitchen remodel markets, which tend to offer higher profit margins than the builder market. As a result, it is possible, according to industry consultants, that small firms would have an easier time passing through increased variable costs that result from standards, and, thus, may be more positively affected by standards than large firms. However this prediction should be tempered by the observation that if standards are technologically difficult to meet, they may hurt selected smaller firms the most because smaller firms have less sophisticated research and development capabilities.

7.3.4 Sensitivity Analysis for Dishwashers

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

As can be seen from the table, three control variables account for nearly all of the uncertainty in the determination of ROE. These are 1) the industry elasticity of demand with respect to operating cost (ICE); 2) the industry elasticity of demand with respect to price (IPE); 3) fixed one time costs (FIX). The reasons why these three variables are important are discussed below.

Sensitivity Charts

Table 7.11 lists the sensitivities of ROE to the control panel inputs.

Table 7.11. Dishwasher Sensitivity Chart

Charts of Sensitivity and Profit for Dishwashers
Sensitivity of ROE to 1 S.E. change in Control Variable

Scenario-Primary Control Variables							
Name	Value	Changed	1	2	3	4	5
IPE	-0.500	-0.772	0.04	0.03	0.00	-0.10	-0.32
ICE	-0.125	-0.229	-0.07	-0.08	0.09	-0.16	-0.28
ECE	0.068	0.075	-0.00	-0.00	-0.01	-0.01	-0.01
EP	0.000	0.010	-0.02	-0.03	-0.05	-0.05	-0.02
FCA	0.100	0.154	-0.02	-0.02	-0.00	0.08	0.24
FIX	0.150	0.247	-0.05	-0.11	-0.21	-0.24	-0.24
CC.L	2.815	3.419	-0.02	-0.04	-0.06	-0.07	-0.09
dVCL	4.770	5.793	0.04	0.04	0.05	0.08	-0.14

Alternative scenarios

The sensitivity analysis shows that both price and operating-cost elasticity play a crucial role in determining the model's output. These are both *industry* elasticities as opposed to single-firm elasticities; this means they measure the effect on demand of a change in price by all firms and a change in operating cost of all dishwashers. The estimates of standard errors that are calculated by the Monte Carlo analysis fully acknowledge the uncertainties of these two variables. However, in order to show in detail all of the ramifications of changing one or both of them, four alternative scenarios have been used. The four scenarios include a low industry operating cost elasticity (ICE) scenario, a low ICE and high industry price elasticity (IPE) scenario, a constant shipments scenario (with ICE and IPE set to zero), and a high ICE scenario. Tables 7.12, 7.13, 7.14, and 7.15 show the results of running these four scenarios for the dishwasher manufacturing industry.

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

Table 7.13 shows that increasing price elasticity also tends to lower ROE. This effect is probably due to the greater decline in shipments when price elasticity is greater. ROE in Table 7.13 is most similar to ROE in the primary scenario as a result of the offsetting effects of a higher IPE and a lower ICE.

Monte Carlo Analysis

The Monte Carlo approach is described in Section 7.2.4, and the standard errors it generates are reported in the output tables. More detail of a Monte Carlo run can be seen on page two of the printouts of the LBL-MIM for dishwashers in Section C.4.1. This section examines two runs in more detail.

Table 7.16 shows the control panels from two Monte Carlo runs, which were selected because they showed a decrease in long-run ROE. All Monte Carlo Runs were done for standards level . In **both** runs, a higher percentage of fixed costs (FCA) and a higher portion of fixed one-time costs, which **do** not get passed through in prices were the primary factors in reducing ROE. Note that in both scenarios shown, one of these variables was randomly chosen to be about two standard deviations* or more beyond its estimated value.

7.4 IMPACTS ON THE MANUFACTURERS OF CLOTHES WASHERS

There have been several changes in the Manufacturer Impact Model since the writing of TSD. The primary changes which affect the clothes washer analysis are the following:

1. Two programming bugs in the LBL-MIM spreadsheet were fixed. The first was to correct the passing through of capital costs in the calculation of retail prices which had overestimated prices of some designs. The second was the revision of the short run calculation formulas to fully agree with the formulas for the long run calculations which had underestimated the short-run impact of several variables;
2. Engineering data has been revised and updated. New design options have been added and others dropped. Also, two product classes are analyzed instead of three.

7.4.1 Long-Run Impacts

Clothes washers were analyzed at trial standards levels 1 through 5 and the base case. For a complete description of these levels, see Chapter 5.

This analysis shows that compared to the 1996 base case, at all trial standards levels except level 3, the clothes washer industry is likely to experience a ROE decrease. At standards level 1, there is approximately a 78% chance that ROE will decrease, and that the expected decrease will be 0.19%. At standards level 2 there is approximately a 60% chance of a decrease in ROE with an expected decrease of 0.06%. At standards level 3 there is approximately a 28% chance of a decrease in ROE with an expected decrease of 0.26%. At standards level 4 the analysis shows approximately a 97% chance of a decrease in ROE with an expected decrease of 4.67%. And at standards level 5 the analysis shows approximately a 97% chance of a decrease in ROE with an expected decrease of 4.89%. These results are based on Table 7.17. The probabilities of change are computed from the expected change, the standard error of this estimate, and the assumption of a normal distribution.

* Technically, when "Ctrl" is set to 2.00, a value for the control factor is chosen that is as unlikely as a value that is 2.00 standard deviations above the mean of a normal distribution. This distinction is meaningful because the control variables are generally represented by highly skewed distributions; they are represented this way because their sign is known, and they are not far from zero.

Table 7.12 Dishwasher Output Table:
Low Industry Operating Cost Elasticity (ICE) Scenario

OUTPUT Table		DISHWASHER					
Scenario=Low ICE		Long Run					
	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5	
Shipments (in Mil)	0.70	0.69	0.69	0.69	0.68	0.67	
% change		-0.92%	-1.11%	-1.60%	-2.78%	-4.55%	
S.E.		0.26%	0.30%	0.32%	0.52%	0.86%	
Price	\$215.36	\$219.38	\$220.24	\$222.42	\$227.85	\$236.36	
% change		1.87%	2.27%	3.28%	5.80%	9.75%	
S.E.		0.55%	0.62%	0.68%	1.15%	1.99%	
Revenue (in \$M)	150.08	151.48	151.77	152.52	154.37	157.23	
% change		0.93%	1.13%	1.63%	2.86%	4.76%	
S.E.		0.27%	0.30%	0.34%	0.56%	0.95%	
Net Income (in \$M)	2.44	2.51	2.53	2.56	2.65	2.78	
% change		2.87%	3.46%	4.84%	8.29%	13.75%	
S.E.		2.55%	3.39%	5.41%	7.23%	11.05%	
ROE	6.88%	7.04%	7.01%	6.94%	7.20%	7.69%	
Difference		0.17%	0.13%	0.07%	0.32%	0.81%	
S.E.		0.19%	0.23%	0.35%	0.50%	0.79%	

Table 7.13 Dishwasher Output Table:
High Industry Price Elasticity (IPE) and Low ICE Scenario

OUTPUT Table DISHWASHER		Long Run					
Scenario=Lo ICE & Hi IPE		1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	0.69	0.68	0.68	0.67	0.66	0.63	
% change		-1.83%	-2.22%	-3.18%	-5.48%	-8.89%	
S.E.		0.48%	0.54%	0.71%	1.11%	1.59%	
Price	\$215.36	\$219.38	\$220.24	\$222.43	\$227.85	\$236.36	
% change		1.87%	2.27%	3.28%	5.80%	9.75%	
S.E.		0.50%	0.57%	0.76%	1.25%	1.92%	
Revenue (in \$M)	149.41	149.41	149.41	149.41	149.41	149.41	
% change		0.00%	0.00%	0.00%	0.00%	0.00%	
S.E.		0.00%	0.00%	0.00%	0.00%	0.00%	
Net Income (in \$M)	2.39	2.34	2.33	2.29	2.22	2.11	
% change		-1.95%	-2.49%	-4.00%	-7.18%	-11.72%	
S.E.		0.89%	1.86%	3.02%	3.83%	4.64%	
ROE	6.75%	6.65%	6.55%	6.33%	6.21%	6.11%	
Difference		-0.10%	-0.20%	-0.42%	-0.54%	-0.64%	
S.E.		0.06%	0.12%	0.20%	0.23%	0.27%	

**Table 7.14 Dishwasher Output Table:
Constant Shipments Scenario**

OUTPUT Table DISHWASHER		Long Run					
Scenario=Const. Shipmts		1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)		0.70	0.70	0.70	0.70	0.70	0.70
% change			0.00%	0.00%	-0.00%	-0.00%	-0.00%
S.E.			0.00%	0.00%	0.00%	0.00%	0.00%
Price		\$215.20	\$218.74	\$219.54	\$221.56	\$226.71	\$234.96
% change			1.64%	2.02%	2.95%	5.35%	9.18%
S.E.			0.50%	0.53%	0.66%	1.16%	2.01%
Revenue (in \$M)		150.64	153.12	153.68	155.09	158.70	164.47
% change			1.64%	2.02%	2.95%	5.35%	9.18%
S.E.			0.50%	0.53%	0.66%	1.16%	2.01%
Net Income (in \$M)		2.43	2.39	2.41	2.44	2.56	2.84
% change			-1.45%	-0.78%	0.38%	5.65%	16.87%
S.E.			2.80%	3.05%	4.36%	7.34%	18.40%
ROE		6.80%	6.61%	6.57%	6.48%	6.77%	7.49%
Difference			-0.18%	-0.22%	-0.32%	-0.03%	0.69%
S.E.			0.18%	0.19%	0.26%	0.46%	1.09%

**Table 7.15 Dishwasher Output Table:
High ICE Scenario**

OUTPUT Table DISHWASHER		Long Run					
Scenario=High ICE		1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)		0.70	0.71	0.71	0.71	0.71	0.70
% change			1.40%	1.42%	1.62%	1.26%	-0.21%
S.E.			0.25%	0.29%	0.36%	0.59%	0.92%
Price		\$215.10	\$218.33	\$219.10	\$221.00	\$225.98	\$234.05
% change			1.50%	1.86%	2.74%	5.06%	8.81%
S.E.			0.47%	0.56%	0.69%	1.14%	1.84%
Revenue (in \$M)		150.91	155.31	155.89	157.57	160.54	163.86
% change			2.92%	3.30%	4.41%	6.38%	3.58%
S.E.			0.23%	0.27%	0.33%	0.53%	0.82%
Net Income (in \$M)		2.41	2.40	2.41	2.42	2.42	2.42
% change			-0.28%	-0.09%	0.33%	0.45%	0.49%
S.E.			1.26%	2.25%	3.95%	4.45%	3.47%
ROE		6.73%	6.54%	6.47%	6.32%	6.30%	6.39%
Difference			-0.19%	-0.26%	-0.41%	-0.43%	-0.34%
S.E.			0.09%	0.16%	0.25%	0.29%	0.24%

Table 7.16 Dishwasher Monte Carlo Runs
Searching for Low ROE

Panel	Scenario: Primary		Standard Level - 3		
DISHWASHER	Input		Vari-	Progrm	
CONTROL FACTORS	Value	Cntrl	ation	Value	Name
Price Elasticity	-0.500	-1.43	50%	-0.269	IPE
Operating Cost Elasticity	-0.125	0.39	80%	-0.158	ICE
Equity Cost of Capital	0.068	1.45	10%	0.079	ECC
Economic Profit	0.000	-0.76	0.010	-0.008	EP
L-R Fixed part of Costs & Assets	0.100	0.33	50%	0.115	FCA
L-R Fixed Part of 1-X Cap. Cost	0.150	1.22	60%	0.276	FIX
One-Time Capital Costs	8.349	1.99	20%	12.293	CC.L
Unit Variable Cost Increase	\$6.39	-1.56	20%	4.719	dVC.L
Short Run Price Response to Demand	0.034	-1.05	232%	0.011	SRPR
SUMMARY	NAECA	NEW	PRVIOUS	NEW	
	BASE	L-RUN	CHANGE	S-RUN	
Shipments	0.70	0.71	1.35%	0.23%	0.71
Price	\$215.03	\$219.50	2.08%	1.64%	\$219.54
Revenue (in \$M)	150.81	156.02	3.45%	1.88%	156.04
Net Income	2.48	2.21	-10.81%	-0.24%	2.23
ROE	6.94%	5.65%	-1.29%	-0.12%	5.68%
06/27/90		21:39	Trys -	24.00	

Panel	Scenario: Primary		Standard Level - 3		
DISHWASHER	Input		Vari-	Progrm	
CONTROL FACTORS	Value	Cntrl	ation	Value	Name
Price Elasticity	-0.500	-1.63	50%	-0.247	IPE
Operating Cost Elasticity	-0.125	0.15	80%	-0.137	ICE
Equity Cost of Capital	0.068	-1.27	10%	0.060	ECC
Economic Profit	0.000	1.93	0.010	0.019	EP
L-R Fixed part of Costs & Assets	0.100	2.14	50%	0.253	FCA
L-R Fixed Part of 1-X Cap. Cost	0.150	-1.70	60%	0.064	FIX
One-Time Capital Costs	8.349	1.73	20%	11.687	CC.L
Unit Variable Cost Increase	\$6.39	-0.62	20%	5.657	dVC.L
Short Run Price Response to Demand	0.034	-0.95	232%	0.013	SRPR
SUMMARY	NAECA	NEW	PRVIOUS	NEW	
	BASE	L-RUN	CHANGE	S-RUN	
Shipments	0.70	0.71	1.09%	-0.00%	0.71
Price	\$214.94	\$219.86	2.29%	2.95%	\$219.89
Revenue (in \$M)	150.71	155.83	3.40%	2.95%	155.85
Net Income	2.75	2.43	-11.51%	0.34%	2.15
ROE	7.70%	6.27%	-1.43%	-0.32%	6.30%
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Table 7.17. Clothes Washer Output Table: Primary Scenario

Output Table - Clothes Washer
Scenario-Primary

	1996 Base	Long Run Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments in (MIL)	1.11	1.12	1.11	1.10	1.05	1.03
Change (%)		0.38	0.03	-1.11	-6.15	-7.85
S.E. (%)		0.39	0.47	1.02	4.97	5.17
Price (\$)	279.74	279.83	283.41	294.31	371.28	392.01
Change (%)		0.03	1.31	5.21	32.72	40.14
S.E. (%)		0.58	0.67	1.32	8.14	8.44
Revenue in (\$MIL)	311.67	312.94	315.86	324.27	388.20	402.46
Change (%)		1.88	2.17	2.95	4.51	6.53
Change (%)		0.41	1.34	4.04	24.56	29.13
S.E. (%)		0.46	0.58	1.15	7.38	8.27
Net Income (in \$MIL)	5.094.99	5.09	5.41	3.58	3.03	
Change (%)		-1.98	-0.13	6.11	-29.79	-40.43
S.E. (%)		4.21	4.68	8.01	192.48	214.52
ROE (%)		6.05	5.86	5.99	6.31	1.38
Difference		-0.19	-0.06	0.26	-4.67	-4.89
S.E. (%)		0.24	0.25	0.45	2.41	2.64

Qualitative analysis

According to reports from within the industry, clothes washer manufacturing is characterized by economies of scale, which will tend to increase profit by making clothes washers more economically attractive to consumers, thereby increasing demand. However, this effect is smaller for clothes washers than for most other appliances. Also, the demand function is specified as a function of purchase price and operating cost, i.e., life-cycle cost under constant life-cycle cost elasticity. Therefore, as price changes, so does price elasticity, and consequently, markup. For instance, as prices rises, price elasticity rises, and markup falls. The model calculates that these effects, when combined, are likely to decrease economic profits at all standards levels, except for level 3 where there is a likelihood of a small increase.

Quantitative analysis

Table 7.17, referred to as the long-run output table, summarizes all essential outputs from the LBL-MIM simulations using the primary scenario for clothes washers. Four other scenarios are summarized and discussed in the sensitivity section, 7.4.4. The first column in the output table gives the value of the output variables in the 1996 base case. This case represents the state of the industry in the mid-1990s if the current NAECA standards were to remain unchanged. Each of the next five columns shows the estimated state of the industry in 1996 if one of the corresponding trial standards levels were to be implemented.

Each column of the output table gives the estimated values of the five most important output variables. Under each of these five values can be found two percentages; the upper percentage tells how much the variable has changed from the base case, and the lower percentage gives the standard error 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.

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

7.4.2 Short-Run Impacts

The business cycle presents the clothes washer manufacturing industry with fairly sharp periodic fluctuations in demand, much larger than the fluctuations predicted for any of the standards levels. These normal demand fluctuations present the same types of opportunities for price competition that will accompany fluctuations resulting from a change in standards. Regressing price on demand and a time trend for the past 18 years shows that a 10% fall in demand typically leads to a 0.7% fall in the price of clothes washers; a 10% demand increase has the reverse effect. This effect is taken into account, as described in Section 7.2.2, and is used to produce a short-run version of the output table that is displayed in Table 7.18. Note that at all standards levels analyzed, the short-run ROE results are less than 0.55 percentage points smaller than the long-run results for the clothes washer manufacturing industry. For reasons that are explained in 7.2.2, the short-run change has been over-estimated. Thus, all values for change in Table 7.18 should be viewed as somewhat too large in absolute value. The short-run impact on profit is also displayed in the Monte Carlo module.

Sensitivity Charts

Table 7.18. Clothes Washers: Primary Scenario
Short-Run Output Table

Output Table Clothes Washer Scenario-Primary	1996 Base	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in MIL)	1.11	1.12	1.11	1.10	1.05	1.03
Change (%)		0.37	0.03	-1.08	-5.97	-7.60
Price(\$)	279.74	279.90	283.41	294.08	369.70	389.90
Change (%)		0.06	1.31	5.12	37.16	39.38
Revenue (in \$M)	311.67	313.00	315.86	324.11	387.31	401.37
Change (%)		0.43	1.35	3.99	24.27	28.78
Net Income (in \$M)	5.09	5.04	5.09	5.25	2.67	1.85
Change (%)		-0.97	-0.04	3.04	-47.64	-63.77
ROE (%)	6.05	5.92	5.99	6.13	1.03	0.71
Difference (%)		-0.13	-0.06	-0.07	-5.02	-5.34
S.E. (%)		0.32	0.26	0.58	2.58	2.86

7.4.3 Impact as a Function of Firm Size

A principal implication of the consolidation that has been occurring among appliance manufacturers is that smaller firms will be in more danger of failing or being bought out, on average, than will the large firms. Small firms in the clothes washer manufacturing industry account for 3% of the total market. As a result of economies of scale, small firms face a cost disadvantage when they compete against larger firms in the clothes washer market. Because of this, small firms generally specialize in a niche market that allows them to avoid head-to-head competition with the large firms. Their small size makes cost increases (especially fixed cost increases) more damaging, while their protected niche makes it easier to pass on those cost increases. Because of these conflicting effects and the lack of data on the demand elasticities of small firms, it is impossible to say whether small firms have a greater or lesser probability of experiencing a decrease in average ROE than the larger firms.

From the point of view of competitiveness, a decrease in average profitability could speed up the process of consolidation, producing a less competitive industry, and an increase in average profitability could help maintain the current competition. Either effect might well be temporary because in the long run the number of firms should be determined by the industry's cost structure and by the way a single firm's elasticity of demand relates to the number of competing firms.

7.4.4 Sensitivity Analysis for Clothes Washers

The three following subsections discuss different aspects of the sensitivity analysis conducted by LBL-MIM. The first subsection, on sensitivity charts, shows the implications of the uncertainty of each control variable for the prediction of ROE. The next subsection shows four alternative scenarios that are of particular importance and deserve a more detailed analysis than those randomly generated by Monte Carlo runs. The last subsection shows the use of Monte Carlo runs to find combinations of errors that would cause the change in ROE to be considerably more negative than is predicted. Table 7.19 lists the sensitivities of ROE to the control panel inputs.

Table 7.19. Clothes Washer Sensitivity Chart
Charts of Sensitivity and Profit for Dishwashers
Sensitivity of ROE to 1 S.E. change in Control Variable

Scenario-Primary Control Variables			Possible Standards Levels (Percent)				
Name	Value	Changed	1	2	3	4	5
IPE	-0.300	-0.463	0.08	0.04	-0.10	-1.47	-1.76
ICE	-0.055	-0.101	-0.07	-0.11	-0.20	0.35	0.26
ECC	0.068	0.075	-0.00	-0.00	-0.00	-0.12	-0.13
EP	0.000	0.010	-0.02	-0.01	0.00	-0.55	-0.54
FCA	0.100	0.154	-0.10	-0.01	0.30	0.42	0.58
FIX	0.150	0.247	-0.03	-0.03	0.09	-2.09	-2.08
CC.L	51.384	62.410	-0.12	-0.13	-0.17	-0.70	-0.74
dVCL	2.298	2.791	0.02	0.05	0.14	-0.00	-0.04

As can be seen from the table, four control variables account for nearly all of the uncertainty in the determination of ROE. These are 1) the industry elasticity of demand with respect to cost (ICE); 2) the proportion of fixed one-time costs (F1X); 3) the level of capital costs (CC.L); and 4) the industry elasticity of demand with respect to price (IPE). The relative importance of each variable varies for each standards level. Why the four above-mentioned variables are important and why their importance changes from one level to the next is discussed below.

Alternative scenarios

The sensitivity analysis shows that price and operating-cost elasticities play a crucial role in determining the output of the model. These are both industry elasticities as opposed to single-firm elasticities; this means they measure the effect on demand of a change in price by all firms and a change in operating cost of all clothes washers. The estimates of standard errors that are calculated by the Monte Carlo analysis fully acknowledge the uncertainties of these two variables. However, in order to show in detail all of the ramifications of changing one or both of them, four alternative scenarios have been used. The scenarios include a low industry operating cost elasticity (ICE) scenario, a low ICE and high industry price elasticity (IPE) scenario, a constant shipments scenario (with ICE and IPE set to zero), and a high ICE scenario. Tables 7.20, 7.21, 7.22, and 7.23 show the results of running these four scenarios for the clothes washer manufacturing industry.

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

Table 7.21 shows that increasing price elasticity (IPE) also tends to lower ROE. This effect is probably due to the greater decline in shipments when price elasticity is greater.

Monte Carlo Analysis

The Monte Carlo approach is described in Section 7.2.4, and the standard errors it generates are reported in the output tables. More detail of a Monte Carlo run can be seen on page two of the printouts of the LBL-MIM for clothes washers in Section C.4.2. This section examines two runs in more detail.

Table 7.24 shows the control panel from two Monte Carlo runs, which were selected because they showed a decrease in long-run ROE. All Monte Carlo runs were done for standards level 3. In both of the clothes washer Monte Carlo runs several factors contribute to the negative results.* The primary factors affecting the negative results are changes in industry price elasticity (IPE) and industry operating cost elasticity (ICE), with their resulting effects on markup and profits, in conjunction with either a higher percent of fixed costs (FCA) or an increase in fixed one-time costs, both of which do not get passed through in prices. Both scenarios primarily involve a change in elasticity, which translates into a lower markup and a lower price, along with an increased percentage of fixed costs that do not get passed on, as the chief means of producing a drop in ROE.

7.5 IMPACTS ON THE MANUFACTURERS OF CLOTHES DRYERS

There have been several changes in the Manufacturer Impact Model since the writing of TSD. The primary changes which affect the analysis are the following:

1. Two programming bugs in the LBL-MIM spreadsheet were fixed. The first was to correct the passing through of capital costs in the calculation of retail prices which had overestimated prices of some designs. The second was the revision of the short run calculation formulas to fully agree with the formulas for the long run calculations which had underestimated the short-run impact of several variables.
2. Engineering data has been revised and updated. Two new design options have been added.

The standard LBL-MIM was modified for the analysis of clothes dryers to include the cross elasticity between electric and gas dryers. This was necessary because of the large price changes which at some standards levels occur predominantly in one type of dryer or the other. The magnitude of the cross elasticity was set to agree with the changes in the distribution of shipments predicted by LBL-REM. However, this agreement is not exact at all standards levels because LBL-MIM and LBL-REM do not use the same model of product demand LBL-MIM must estimate shipments internally because of its iterative Monte Carlo

7.5.1 Long-Run Impact:

Clothes dryers were analyzed at trial standards levels 1 through 5 and the base case. For a complete description of these levels, see Chapter 5.

The analysis finds that at trial standards levels 1 and 2, the clothes dryer industry is likely to experience an increase in ROE. At standards levels 3 through 5, there is a strong possibility of an ROE decrease which would force consolidation within the industry before a return to normal profits.

* Note that, technically, when "Cntrl" is set to 2.0, a value for the control factor is chosen that is as unlikely as a value that is 2.0 standard deviations above the mean of a normal distribution. This distinction is meaningful because the control variables are generally represented by highly skewed distributions; they are represented this way because their sign is known, and they are not far from zero.

Table 7.20 Clothes Washer Output Table:
Low Industry Operating Cost Elasticity (ICE) Scenario

OUTPUT Table		CLOTHES WASHERS					
Scenario=Low ICE		Long Run					
	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5	
Shipments (in Mil)	1.11	1.11	1.10	1.09	1.02	1.00	
% change		-0.04%	-0.43%	-1.57%	-8.44%	-9.93%	
S.E.		0.16%	0.20%	0.37%	1.68%	1.58%	
Price	\$280.27	\$280.69	\$284.38	\$295.49	\$376.02	\$397.14	
% change		0.15%	1.47%	5.43%	34.16%	41.70%	
S.E.		0.53%	0.69%	1.31%	8.47%	8.42%	
Revenue (in \$M)	310.73	311.06	313.91	322.45	381.71	396.59	
% change		0.11%	1.02%	3.77%	22.84%	27.63%	
S.E.		0.37%	0.48%	0.90%	5.39%	5.28%	
Net Income (in \$M)	5.34	5.36	5.51	5.96	4.09	3.90	
% change		0.34%	3.20%	11.67%	-23.33%	-26.91%	
S.E.		2.32%	3.18%	9.10%	174.56%	173.08%	
ROE	6.37%	6.34%	6.54%	7.01%	1.60%	1.51%	
Difference		-0.03%	0.17%	0.64%	-4.77%	-4.86%	
S.E.		0.16%	0.23%	0.65%	2.38%	2.39%	

Table 7.21 Clothes Washer Output Table:
High Industry Price Elasticity (IPE) and Low ICE Scenario

OUTPUT Table		CLOTHES WASHERS					
Scenario=Lo ICE & Hi IPE		Long Run					
	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5	
Shipments (in Mil)	1.10	1.10	1.09	1.06	0.92	0.89	
% change		-0.09%	-0.87%	-3.12%	-16.16%	-18.87%	
S.E.		0.31%	0.41%	0.72%	3.01%	3.04%	
Price	\$280.27	\$280.70	\$284.38	\$295.50	\$376.03	\$397.14	
% change		0.15%	1.47%	5.43%	34.16%	41.70%	
S.E.		0.53%	0.70%	1.32%	8.18%	9.21%	
Revenue (in \$M)	307.58	307.77	309.38	314.16	345.96	353.60	
% change		0.06%	0.58%	2.14%	12.48%	14.96%	
S.E.		0.21%	0.28%	0.51%	2.72%	2.94%	
Net Income (in \$M)	5.04	5.04	5.07	5.16	-4.51	-6.15	
% change		0.04%	0.71%	2.42%	-189.57%	-222.01%	
S.E.		2.15%	3.28%	6.66%	191.85%	193.81%	
ROE	6.06%	6.01%	6.09%	6.20%	-1.80%	-2.44%	
Difference		-0.05%	0.03%	0.14%	-7.86%	-8.50%	
S.E.		0.20%	0.26%	0.45%	2.11%	2.03%	

Table 7.22 Clothes Washer Output Table:
Constant Shipments Scenario

OUTPUT Table		CLOTHES WASHERS					
Scenario=Const Shipmts		Long Run					
	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5	
Shipments (in Mil)	1.12	1.12	1.12	1.12	1.12	1.12	
% change		0.00%	0.00%	-0.00%	-0.00%	-0.00%	
S.E.		0.00%	0.00%	0.00%	0.00%	0.00%	
Price	\$279.74	\$279.83	\$283.41	\$294.31	\$371.28	\$392.01	
% change		0.03%	1.31%	5.21%	32.72%	40.14%	
S.E.		0.53%	0.65%	1.37%	8.05%	9.12%	
Revenue (in \$M)	313.30	313.40	317.42	329.63	415.83	439.05	
% change		0.03%	1.31%	5.21%	32.72%	40.14%	
S.E.		0.53%	0.65%	1.37%	8.05%	9.12%	
Net Income (in \$M)	5.25	5.04	5.23	5.91	10.08	11.39	
% change		-4.05%	-0.27%	12.63%	92.05%	116.91%	
S.E.		4.99%	4.17%	10.52%	199.18%	280.34%	
ROE	6.21%	5.90%	6.14%	6.81%	3.83%	4.28%	
Difference		-0.30%	-0.07%	0.60%	-2.38%	-1.93%	
S.E.		0.24%	0.19%	0.60%	2.62%	2.98%	

Table 7.23 Clothes Washer Output Table:
High ICE Scenario

OUTPUT Table		CLOTHES WASHERS					
Scenario=High ICE		Long Run					
	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5	
Shipments (in Mil)	1.12	1.13	1.13	1.11	1.08	1.06	
% change		0.81%	0.51%	-0.62%	-3.43%	-5.34%	
S.E.		0.17%	0.21%	0.39%	2.21%	2.17%	
Price	\$279.36	\$279.21	\$282.72	\$293.47	\$367.90	\$388.37	
% change		-0.05%	1.20%	5.05%	31.70%	39.02%	
S.E.		0.53%	0.67%	1.30%	8.17%	8.54%	
Revenue (in \$M)	312.76	315.12	318.13	326.51	397.75	411.61	
% change		0.75%	1.72%	4.40%	27.17%	31.60%	
S.E.		0.37%	0.46%	0.87%	4.90%	5.01%	
Net Income (in \$M)	4.96	4.81	4.86	5.09	4.28	3.45	
% change		-3.06%	-1.91%	2.62%	-13.75%	-30.33%	
S.E.		4.79%	3.75%	5.65%	157.60%	215.35%	
ROE	5.87%	5.60%	5.68%	5.89%	1.64%	1.32%	
Difference		-0.27%	-0.19%	0.03%	-4.22%	-4.55%	
S.E.		0.24%	0.20%	0.28%	1.90%	2.05%	

Table 7.24 Clothes Washer Monte Carlo Runs
Searching for Low ROE

Panel	Scenario: Primary		Standard Level - 3		
CLOTHES WASHERS	Input		Vari-	Progrm	
CONTROL FACTORS	Value	Cntrl	ation	Value	Name
Price Elasticity	-0.300	-1.80	50%	-0.137	IPE
Operating Cost Elasticity	-0.055	1.02	80%	-0.102	ICE
Equity Cost of Capital	0.068	-0.38	10%	0.065	ECC
Economic Profit	0.000	1.55	0.010	0.016	EP
L-R Fixed part of Costs & Assets	0.100	-0.11	50%	0.096	FCA
L-R Fixed Part of 1-X Cap. Cost	0.150	1.55	60%	0.324	FIX
One-Time Capital Costs	57.162	1.88	20%	82.316	CC.L
Unit Variable Cost Increase	\$14.88	-0.62	20%	13.178	dVC.L
Short Run Price Response to Demand	0.071	0.06	259%	0.076	SRPR

	NAECA	NEW		PRVIOUS	NEW
SUMMARY	BASE	L-RUN	CHANGE	CHANGE	S-RUN
Shipments	1.13	1.13	0.15%	0.38%	1.13
Price	\$277.46	\$291.56	5.08%	0.03%	\$291.59
Revenue (in \$M)	312.33	328.70	5.24%	0.41%	328.73
Net Income	4.65	3.97	-14.81%	-1.98%	3.99
ROE	5.49%	4.23%	-1.26%	-0.19%	4.26%

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Panel	Scenario: Primary		Standard Level - 3		
CLOTHES WASHERS	Input		Vari-	Progrm	
CONTROL FACTORS	Value	Cntrl	ation	Value	Name
Price Elasticity	-0.300	-0.75	50%	-0.217	IPE
Operating Cost Elasticity	-0.055	0.99	90%	-0.100	ICE
Equity Cost of Capital	0.068	0.42	10%	0.071	ECC
Economic Profit	0.000	1.80	0.010	0.018	EP
L-R Fixed part of Costs & Assets	0.100	-0.95	50%	0.066	FCA
L-R Fixed Part of 1-X Cap. Cost	0.150	1.34	60%	0.293	FIX
One-Time Capital Costs	57.162	2.32	20%	89.774	CC.L
Unit Variable Cost Increase	\$14.88	-1.52	20%	11.075	dVC.L
Short Run Price Response to Demand	0.071	-0.24	259%	0.055	SRPR

	NAECA	NEW		PRVIOUS	NEW
SUMMARY	BASE	L-RUN	CHANGE	CHANGE	S-RUN
Shipments	1.12	1.12	-0.22%	-1.11%	1.12
Price	\$278.20	\$291.52	4.79%	5.21%	\$291.48
Revenue (in \$M)	312.32	326.54	4.55%	4.04%	326.51
Net Income	5.67	5.14	-9.28%	6.11%	5.12
ROE	6.69%	5.39%	-1.30%	0.26%	5.37%

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This analysis shows that at standards level 1, there is approximately a 23% chance that ROE will decrease, and that the expected decrease is 2.8%. At standards level 2 the analysis shows approximately a 42% chance of an decrease in ROE with an expected decrease of 1.1%. At standards level 3 it shows approximately a 74% chance of an decrease in ROE with an expected decrease of 9.1%. At standards level 4 there is approximately a 76% chance of a decrease in ROE with an expected decrease of 22.3%. At standards level 5 the analysis shows approximately a 75% chance of an decrease in ROE with an expected decrease of 37.1%. These results are based on Table 7.25. The probabilities of change are computed from the expected change, the standard error of this estimate, and the assumption of a normal distribution.

Qualitative analysis

According to reports from within the industry, clothes dryer manufacturing is characterized by economies of scale, which means that for the purpose of price determination, there are fixed costs. These are estimated to be about 10% of total costs. Increases in fixed costs *cannot* be passed on, which implies that the markup over variable cost must be approximately 10% if the typical firm is to have a near-average ROE. To the extent that this markup is the same after standards are imposed, and the the extent that standards induce an increase in variable costs, such costs will be more than completely passed on in the form of a price increase which in itself is profitable, but which also tends to reduce profit because of the effect of a price increase on sales. If standards induce an increase in fixed cost, this cost cannot be passed on and will negatively influence profit. Because of the mandated increase in efficiency, operating costs will necessarily decline, which will tend to increase profit by making clothes dryers more attractive and, thereby increase demand. Also, the demand function is specified as a function of purchase price and operating cost, i.e., life-cycle cost, under constant life-cycle cost elasticity. Therefore, as price changes, so does price elasticity, and consequently, markup. For instance, as prices rises, price elasticity rises, and markup falls. The model calculates that these effects, when combined, are more likely to increase economic profits than reduce them at standards levels 1 and 2, and are more likely to reduce economic profits than increase them at standards levels 3 through 5.

Quantitative analysis

Table 7.17, referred to as the long-run output table, summarizes all essential outputs from the LBL-MIM simulations using the primary scenario for clothes dryers. Four other scenarios are summarized and discussed in the sensitivity section, 7.5.4.

Once the above interpretations are understood, the results of the model concerning the long-run impact of standards on the clothes dryer manufacturing industry can be read from the output table. Uncertainty in the output variables increases at high standards levels, approximately in proportion to the size of the change.

**Table 7.25. Clothes Dryer Output Table: Primary Scenario
Long-Run Output Table**

Output Table Clothes Dryers Scenario-Primary	Long Run					
	1996 Base	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in MIL)	0.80	0.81	0.80	0.76	0.73	0.70
Change (%)		0.80	-0.10	-4.60	-9.00	-12.90
S.E. (%)		1.50	2.10	5.10	7.90	12.50
Price(\$)	210.50	215.00	22.30	255.60	294.90	337.50
Change		2.10	5.60	21.50	40.10	60.40
S.E.		0.40	1.10	4.00	8.70	12.40
Revenue (in \$M)	168.40	173.40	177.70	195.00	214.70	235.30
Change (%)		3.00	5.50	15.80	27.50	39.70
S.E. (%)		1.50	2.30	6.10	11.40	18.50
Net Income (in \$M)	2.71	3.90	3.25	-1.10	-6.74	-13.40
Change (%)		43.60	19.80	-140.50	-348.50	-593.60
S.E. (%)		64.20	100.80	268.80	480.00	887.20
ROE (%)	6.80	9.60	7.90	-2.30	-15.50	-30.30
Difference		2.80	1.10	9.10	-22.30	-37.10
S.E. (%)		3.80	5.70	14.40	30.90	55.80

7.5.2 Short-Run Impacts

The business cycle presents the clothes dryer manufacturing industry with fairly sharp periodic fluctuations in demand, much larger than the fluctuations predicted for any of the standards levels. These normal demand fluctuations present the same types of opportunities for price competition that will accompany fluctuations resulting from a change in standards. Regressing price on demand and a time trend for the past 18 years shows that a 10% fall in demand typically leads to a 1.2% fall in the price of clothes dryers; a 10% demand increase has the reverse effect. This effect is taken into account, as described in Section 7.2.2, and is used to produce a short-run version of the output table that is displayed in Table 7.26 The short-run impact on profit is also displayed in the Monte Carlo module.

**Table 7.26. Clothes Dryer: Primary Scenario
Short-Run Output Table**

Output Table Clothes Dryers Scenario-Primary		Short Run			
	1996 Base	Lev 1	Lev 2	Lev 3	Lev 4
Shipments (in MIL)	0.80	0.81	0.80	0.76	0.73
Change (%)	0.08	-0.10	-4.40	-8.40	-11.80
Price(\$)	210.50	215.20	222.30	254.30	292.00
Change (%)		2.20	5.60	20.80	38.70
Revenue (in \$M)	168.40	173.50	177.70	194.60	214.00
Change (%)		3.00	5.50	15.50	27.10
Net Income (in \$M)	2.71	3.96	3.25	-1.41	-7.21
Change (%)		45.90	19.60	-151.80	-365.70
ROE (%)	6.80	9.80	7.90	-2.90	-16.60
Difference (%)		3.00	1.10	-9.70	-23.40
S.E. (%)		4.10	6.10	14.20	29.20

7.5.3 Impact as a Function of Firm Size

A principal implication of the consolidation that has been occurring among appliance manufacturers is that the smaller firms will be, on average, in more danger of failing or being bought out than will the large firms. Small firms in the clothes dryer manufacturing industry account for 3% of the total market. As a result of economies of scale, small firms face a cost disadvantage as they compete against larger firms in the clothes dryer market. Because of this, small firms generally specialize in a niche market that allows them to avoid head-to-head competition with the large firms. Their small size makes cost increases, especially fixed cost increases, more damaging, while their protected niche makes it easier to pass on those cost increases. Because of these conflicting effects and the lack of data on the demand elasticities of small firms, it is impossible to say whether small firms have a greater or lesser probability of experiencing a decrease in average ROE than the larger firms.

From the point of view of competitiveness, a decrease in average profitability could speed up the process of consolidation, producing a less competitive industry, and an increase in average profitability could help maintain the current competition. Either effect might well be temporary because in the long run the number of firms should be determined by the industry's cost structure and by the way a single firm's elasticity of demand relates to the number of competing firms.

7.5.4 Sensitivity Analysis for Clothes Dryers

Sensitivity Charts

Table 7.27 lists the sensitivities of ROE to the control panel inputs.

Table 7.27. Clothes Dryer Sensitivity Chart
Charts of Sensitivity and Profit for Clothes Dryers
Sensitivity of ROE to 1 S.E. change in Control Variable

Control Variables Name		Scenario-Primary						
		Value						
IPE	-0.400	-0.617	-1.29	-3.38	-11.80	-26.60	-42.58	
ICE	-0.257	-0.471	3.82	4.93	7.49	16.01	-32.83	
ECC	0.068	0.075	-0.01	-0.01	-0.06	-0.00	-0.01	
EP	0.000	0.010	-0.00	-0.00	-0.07	0.09	0.06	
FCA	0.100	0.154	0.23	0.58	1.68	2.72	2.53	
F1X	0.150	0.247	-0.03	-0.09	-0.50	-0.36	-0.41	
CC.L	1.423	1.729	-0.04	-0.14	-0.33	-0.12	-0.21	
dVC.L	3.812	4.630	-0.34	-0.92	-3.40	-10.68	-21.16	

As can be seen from the table, three control variables account for nearly all of the uncertainty in the determination of ROE. These are: 1) industry elasticity of demand with respect to operating cost (ICE), 2) industry elasticity of demand with respect to price (IPE), and 3) the incremental variable costs resulting from standards (dVC.L).

Alternative scenarios

The sensitivity analysis shows that price and operating-cost elasticities play a crucial role in determining the output of the model. These are both industry elasticities as opposed to single-firm elasticities; this means they measure the effect on demand of a change in price by all firms and a change in operating cost of all clothes dryers. The estimates of standard errors that are calculated by the Monte Carlo analysis fully acknowledge the uncertainties of these two variables. However, in order to show in detail all of the ramifications of changing one or both of them, four alternative scenarios have been used. The scenarios include a low industry operating cost elasticity (ICE) scenario, a low ICE and high industry price elasticity (IPE) scenario, a constant shipments scenario (with ICE and IPE set to zero), and a high ICE scenario. Tables 7.28, 7.29, 7.30, and 7.31 show the results of running these four scenarios for the clothes dryer manufacturing industry.

In these alternative scenarios, note the impact of changes both in ICE and IPE. A high ICE input value increases ROE, and a lower ICE value decreases ROE. In each of the low ICE scenarios, the ROE results are lower than the primary scenario. In addition, a high IPE value results in a further decrease in ROE, as can be seen in Table 7.29. Both price and operating cost elasticities affect sales, and decreasing sales generally lowers ROE. Note that the constant shipments scenario and the high ICE scenario result in higher ROEs than the base case.

Monte Carlo Analysis

The Monte Carlo approach is described in Section 7.2.4, and the standard errors it generates are reported in the output tables. More detail of a Monte Carlo run can be seen on page two of the printouts of the LBL-MIM for clothes dryers in Section C.4.3. This section examines two runs in more detail.

Table 7.32 shows the control panel from two Monte Carlo runs, which were selected because they showed a decrease in long-run ROE. All Monte Carlo runs were done for standard level 3. In both of the clothes dryer Monte Carlo runs, the primary factor affecting the results was IPE, the industry's price elasticity. A high price elasticity leads to a drop in sales when prices are increased. Both of the scenarios shown here involve a rather large drop in sales, and this decrease is the main reason ROE decreases.

7.6 REFERENCES

1. Comments by dishwasher manufacturing industry consultants at a meeting in Chicago on August 22, 1988.

Table 7.28 Clothes Dryer Output Table:
Low Industry Operating Cost Elasticity (ICE) Scenario

OUTPUT Table Scenario=	CLOTHES DRYERS					
	Low ICE	Long Run				
	96 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (\$M)	0.80	0.79	0.78	0.74	0.70	0.65
% change		-0.8%	-2.1%	-7.4%	-13.0%	-19.3%
S.E.		0.2%	0.4%	1.2%	2.2%	3.2%
Price	\$210.5	\$215.0	\$222.3	\$255.6	\$294.9	\$337.5
% change		2.1%	5.6%	21.5%	40.1%	60.4%
S.E.		0.4%	1.1%	4.0%	8.3%	12.6%
Revenue (\$M)	\$168.4	\$170.6	\$174.1	\$189.4	\$205.3	\$217.9
% change		1.3%	3.4%	12.5%	21.9%	29.4%
S.E.		0.3%	0.6%	2.2%	3.9%	4.7%
Net Income (\$M)	2.71	2.01	0.84	-4.83	-12.98	-24.92
% change		-26.0%	-69.0%	-277.8%	-578.2%	-1018.0%
S.E.		7.0%	22.0%	89.7%	204.1%	317.3%
ROE	6.8%	5.0%	2.1%	-10.2%	-31.0%	-59.8%
Difference		-1.8%	-4.7%	-17.0%	-37.8%	-66.6%
S.E.		0.4%	1.0%	3.5%	10.0%	18.3%

Table 7.29 Clothes Dryer Output Table:
High Industry Price Elasticity (IPE) and Low ICE Scenario

OUTPUT Table Scenario=	CLOTHES DRYERS					
	Lo ICE & Hi IPE	Long Run				
	96 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (\$M)	0.80	0.79	0.77	0.69	0.61	0.53
% change		-1.7%	-4.3%	-14.3%	-24.0%	-33.2%
S.E.		0.3%	0.8%	2.1%	3.5%	4.8%
Price	\$210.5	\$215.0	\$222.3	\$255.6	\$294.9	\$337.5
% change		2.1%	5.6%	21.5%	40.1%	60.4%
S.E.		0.4%	1.1%	3.9%	7.9%	13.2%
Revenue (\$M)	\$168.4	\$169.1	\$170.3	\$175.2	\$179.4	\$180.4
% change		0.4%	1.1%	4.1%	6.5%	7.1%
S.E.		0.1%	0.2%	0.7%	0.9%	0.6%
Net Income (\$M)	2.71	1.06	-1.65	-14.17	-30.08	-49.67
% change		-61.0%	-160.7%	-622.2%	-1207.9%	-1929.7%
S.E.		17.4%	44.3%	168.4%	342.8%	601.7%
ROE	6.8%	2.7%	-4.2%	-31.9%	-79.9%	-136.9%
Difference		-4.1%	-11.0%	-38.7%	-86.7%	-143.7%
S.E.		0.8%	2.1%	7.1%	19.8%	40.8%

**Table 7.30 Clothes Dryer Output Table:
Constant Shipments Scenario**

OUTPUT Table Scenario=	CLOTHES DRYERS					
	Const Shpmts	Long Run				
	96 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (\$M)	0.80	0.80	0.80	0.80	0.80	0.78
% change		0.0%	0.0%	0.1%	-0.4%	-2.5%
S.E.		0.0%	0.0%	0.0%	0.2%	1.0%
Price	\$210.5	\$215.0	\$222.3	\$255.6	\$294.9	\$337.5
% change		2.1%	5.6%	21.5%	40.1%	60.4%
S.E.		0.4%	1.1%	3.8%	7.3%	12.5%
Revenue (\$M)	\$168.4	\$172.0	\$177.9	\$204.7	\$234.9	\$263.2
% change		2.2%	5.7%	21.6%	39.5%	56.3%
S.E.		0.4%	1.1%	3.8%	6.9%	10.6%
Net Income (\$M)	2.71	2.97	3.39	5.28	6.58	4.98
% change		9.4%	24.7%	94.4%	142.4%	83.4%
S.E.		6.9%	19.6%	60.9%	100.9%	138.6%
ROE	6.8%	7.4%	8.2%	10.5%	14.1%	10.3%
Difference		0.6%	1.4%	3.7%	7.3%	3.5%
S.E.		0.4%	1.2%	3.2%	5.4%	7.5%

**Table 7.31 Clothes Dryer Output Table:
High ICE Scenario**

OUTPUT Table Scenario=	CLOTHES DRYERS					
	High ICE	Long Run				
	96 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (\$M)	0.80	0.82	0.82	0.79	0.77	0.78
% change		2.6%	2.1%	-1.3%	-3.5%	-2.8%
S.E.		0.2%	0.4%	1.4%	3.2%	5.5%
Price	\$210.5	\$215.0	\$222.3	\$255.6	\$294.9	\$337.5
% change		2.1%	5.6%	21.5%	40.1%	60.4%
S.E.		0.4%	1.1%	3.8%	8.2%	12.1%
Revenue (\$M)	\$168.4	\$176.4	\$181.6	\$201.8	\$227.6	\$262.5
% change		4.8%	7.8%	19.8%	35.2%	55.9%
S.E.		0.2%	0.6%	1.9%	3.1%	2.7%
Net Income (\$M)	2.71	5.86	5.81	3.34	1.75	4.57
% change		115.8%	114.2%	23.2%	-35.5%	68.2%
S.E.		25.1%	27.0%	65.6%	164.4%	339.9%
ROE	6.8%	14.2%	13.8%	6.8%	3.8%	9.5%
Difference		7.4%	7.0%	-0.0%	-3.0%	2.7%
S.E.		0.4%	1.0%	3.4%	9.4%	18.6%

Table 7.32 Clothes Dryer Monte Carlo Runs
Searching for Low ROE

Panel	Scenario: Primary		Standard Level - 3		
CLOTHES DRYERS	Input		Vari-	Progrm	Name
CONTROL FACTORS	Value	Cntrl	ation	Value	
Price Elasticity	-0.400	1.92	50%	-0.921	IPE
Operating Cost Elasticity	-0.257	-1.64	80%	-0.095	ICE
Equity Cost of Capital	0.068	0.46	10%	0.071	ECC
Economic Profit	0.000	1.20	0.010	0.012	EP
L-R Fixed part of Costs & Assets	0.100	-1.20	50%	0.060	FCA
L-R Fixed Part of 1-X Cap. Cost	0.150	-0.24	60%	0.133	FIX
One-Time Capital Costs	38.943	-0.76	20%	33.624	CC.L
Unit Variable Cost Increase	\$33.71	-0.53	20%	30.397	dVC.L
Short Run Price Response to Demand	0.116	1.04	90%	0.228	SRPR
	0.92	0.86	1.14	0.88	0.96
	0.8644				
SUMMARY	NAECA	NEW	PRVIOUS	NEW	
	BASE	L-RUN	CHANGE	S-RUN	
Shipments	0.8000	0.6916	-13.56%	0.83%	0.71
Price	\$210.49	\$249.53	18.54%	2.15%	\$243.39
Revenue (in \$M)	168.39	172.56	2.48%	2.99%	173.77
Net Income	3.32	-13.09	-4.94	0.44	-12.29
ROE	8.31%	-30.17%	-38.48%	2.80%	-28.34%
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Panel	Scenario: Primary		Standard Level - 3		
CLOTHES DRYERS	Input		Vari-	Progrm	Name
CONTROL FACTORS	Value	Cntrl	ation	Value	
Price Elasticity	-0.400	1.55	50%	-0.784	IPE
Operating Cost Elasticity	-0.257	0.17	80%	-0.285	ICE
Equity Cost of Capital	0.068	0.87	10%	0.074	ECC
Economic Profit	0.000	0.79	0.010	0.008	EP
L-R Fixed part of Costs & Assets	0.100	0.54	50%	0.126	FCA
L-R Fixed Part of 1-X Cap. Cost	0.150	1.25	60%	0.280	FIX
One-Time Capital Costs	38.943	-1.25	20%	30.529	CC.L
Unit Variable Cost Increase	\$33.71	1.43	20%	44.528	dVC.L
Short Run Price Response to Demand	0.116	-0.71	90%	0.073	SRPR
	0.92	0.85	1.14	0.88	0.96
	0.8539				
SUMMARY	NAECA	NEW	PRVIOUS	NEW	
	BASE	L-RUN	CHANGE	S-RUN	
Shipments	0.8000	0.6832	-14.61%	-4.64%	0.69
Price	\$210.49	\$267.05	26.87%	21.45%	\$264.41
Revenue (in \$M)	168.39	182.44	8.34%	15.82%	182.89
Net Income	3.28	-13.79	-5.21	-1.40	-13.50
ROE	8.21%	-32.61%	-40.82%	-9.08%	-31.91%
02/20/90 11:18 Trys - 42.00					

8. IMPACTS OF STANDARDS ON ELECTRIC UTILITIES

8.1 INTRODUCTION

Appliance standards have three 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, and 3) they reduce revenues from electricity sales. The second section of this chapter presents the results of the avoided cost calculations. The third section presents the expected peak load and reliability savings for the analyzed standard levels. The fourth section presents the results of the revenue loss calculation. Section 2.4 summarizes the methods used to calculate avoided costs, the amount and time that new generating capacity is deferred, and the reduction in utility revenues. More details may be found in Appendix D of the previous TSD (1).

8.2 AVOIDED ENERGY AND AVOIDED RELIABILITY COSTS

Figures 8.1 and 8.2 show avoided energy and reliability costs for electricity savings from clothes washers and dryers and from dishwashers, respectively. The difference in these avoided costs is caused by the difference in conservation load factor between clothes washers and dryers (0.63) and dishwashers (0.76), which leads to total avoided costs for dishwashers that are \$0.106 per million Btu (or 2-3%) lower than those for washers and dryers in 2000. These figures show the sum of avoided costs for the base-, high-, and low-energy price cases.* The value per million Btu (MMBtu) of avoided reliability costs is the same in all three energy price cases. The avoided fuel and capital component depends on fuel prices, and varies among the three cases. As explained in Appendix D of the previous Technical Support Document (1), this component implicitly contains the costs avoided when baseload power plants are deferred or canceled.

These avoided costs represent a simple summary of the utility analysis, and they are a measure of the societal benefit of the electricity saved in each year. They can be used in the LBL-REM to value electricity savings from the societal perspective.

8.3. PEAK LOAD AND CAPACITY REDUCTIONS

Tables 8.1 to 8.3 show peak load reductions for the three electric appliances and the relevant standard levels. Tables 8.4 to 8.6 show capacity savings for the three electric appliances and the relevant standard levels. The base case peak load in the second column of Tables 8.1 to 8.3 represents coincident peak load of all such appliances in the residential sector. The total peak demand and the savings are calculated using the appropriate conservation load factors, a transmission and distribution loss factor of 1.06, and estimates of energy consumption calculated using the LBL-REM.

* Fuel price forecasts for the period 1990 to 2000 are taken from the DOE/EIA *Annual energy outlook*, 1989. (2) The forecasts for years after 2000 were linearly extrapolated using the methodology described in Chapter 4. The high and low energy price cases are discussed in Chapter 5.

Total Avoided Costs: Washers and Dryers
(1987 \$/MMBtu)

Figure 8.1. Utility Avoided Costs — Clothes Washers and Dryers

Total Avoided Costs: Dishwashers (1987 \$/MMBtu)

Figure 8.2. Utility Avoided Costs — Dishwashers

Capacity savings are peak load savings in regions that need additional capacity, multiplied by 1.2 to account for reserve margin needed for adequate reliability. The amount of capacity saved can be somewhat less than the peak demand savings in years before 1996 because capacity savings are only counted in regions that need capacity. After 1996, capacity savings consistently exceed peak load savings by the reserve margin of 20% (numbers may not exactly correspond to this rule because of rounding error).

Peak demand reductions from the standards for electric dryers range from 0.3 to 3.8 G* in 2000, and from 0.7 to 8.9 GW in 2015. Capacity savings for electric dryers range from 0.4 to 4.6 GW in 2000, and from 0.9 to 10.7 GW in 2015.

Peak demand reductions from the standards for dishwashers range from 0.1 to 0.3 GW in 2000, and from 0.3 to 0.6 GW in 2015. Capacity savings for dishwashers range from 0.1 to 0.4 GW in 2000, and from 0.3 to 0.7 GW in 2015.

Peak demand reductions from the standards for clothes washers range from 0.2 to 2.3 GW in 2000, and from 0.4 to 4.6 GW in 2015. Capacity savings for clothes washers range from 0.3 to 2.7 GW in 2000, and from 0.5 to 5.6 GW in 2015.

8.4 REVENUE LOSSES

Appliance standards allow utilities to avoid the variable costs of generating electricity, but standards also reduce electricity sales.

In a rate case, the utility and the regulators agree on the revenue requirements and rates based on some estimate of future sales. If the effects of appliance efficiency standards are not included in this forecast, actual sales will be less than forecasted sales, which implies that the utility will not be able to recover some of the fixed costs that were included in the original revenue requirements calculation. This effect can be eliminated if electric utilities and regulators, when calculating rates, use the most current information on the impacts of appliance efficiency standards.

Utilities routinely petition regulators for changes in rates. In the course of such a petition the utility's forecasted sales can be adjusted to account for the appliance efficiency standards and hence eliminate these "lost" revenues. Those revenues lost as a result of time lags in regulation are not a true economic cost, but are a transfer payment from the utility to utility customers. The size of this transfer payment depends on regulatory behavior and on the net change in revenues, which is equal to the difference between sales reductions and avoided costs.

Since the magnitude of these losses is dependent on assumptions about regulatory behavior, and because this behavior is so varied among states, it is difficult to do this calculation for the nation. An additional complication is that unanticipated sales growth from other sectors may compensate for the revenue shortfall. Two cases are presented here, one which assumes that regulators adjust the rates to reflect the reduced sales in five years, and one which assumes that they never adjust the rates. These cases also assume that there is no unanticipated sales growth. These results are presented both on a year-by-year and a present-value basis.

It is possible that the regulators could adjust the rates in anticipation of the new standards, in which case there would be no revenue impact at all. It is also possible that the regulators would not grant rate relief for several years after the standards go into effect, which is approximated by

* 1 GW = 1 Gigawatt = 1 million kilowatts = 1-1000 MW baseload power plant. 1 MW = 1 Megawatt = 1 thousand kilowatts.

the five-year-lag case. While it is unlikely that regulators would never adjust the rates to reflect the post-standard sales forecast, this case is included as an absolute upper bound. Figures 8.3 through 8.5 show annual revenue losses and avoided costs over time for level 3 standards, and Tables 8.7 to 8.9 show net revenue losses for all standards levels. The figures show utility revenue losses, assuming no regulatory adjustment. When this adjustment is made, rates will be increased over the base case forecast, and utilities will cease to lose revenue. Total residential rates would increase 0.24% and 0.46% (0.015 cents/kWh and 0.031 cents/kWh) in 1996 and 2000, respectively, if all three appliances are subject to level 3 standards and regulators only change residential rates to compensate for any loss in revenue.*

Cumulative net revenue losses over the period 1993-2015 for electric clothes dryers range from \$1.3 to 4.2 billion. For dishwashers, the cumulative losses range from \$0.4 billion at level 1 to \$0.8 billion at level 3. Clothes washer net losses range from \$0.4 to 1.2 billion.

Tables 8.10 to 8.12 show the present value of net revenue losses at a 10.2% nominal utility discount rate for all standard levels and for the two assumptions about regulatory behavior. This discount rate is based on an assumed average utility capital structure and current rates of return.* For clothes dryers, the present value of net lost revenues may range from \$84 to 266 million for a five-year lag, and would be as large as \$1.8 billion if the regulators did not adjust. For dishwashers, the present value of net lost revenues may range from \$47 to 77 million for a five-year lag, and would be as large as \$365 million if the regulators did not adjust. For electric clothes washers, the present value of net lost revenues may range from \$61 to 140 million for a five-year lag, and would be as large as \$586 million if the regulators did not adjust. The present values over the period 1993 to 2015 also represent the rate increases needed over this period to compensate for lost revenues, assuming that regulators adjust immediately.

8.5. SENSITIVITY ANALYSIS

Tables 8.13 to 8.14 show the peak demand reductions and capacity savings for sensitivity cases 4, 7, and 8 (described in Chapter 5). These cases were chosen because they span the range of forecasted energy savings from the standards. Tables 8.15 to 8.16 show the present value of net lost revenues for the same sensitivity cases. The assumptions for the sensitivity cases are the same as those for previous tables.

8.6 REFERENCES

1. U.S. Department of Energy. 1988. "Technical Support Document for the Analysis of Efficiency Standards on Refrigerators, Refrigerator-Freezers, Freezers, Small Gas Furnaces and Television Sets", (March).
- (2) U.S. Department of Energy. 1989. *Annual energy outlook, 1989*. DOE/EIA-0383(89).

* At a 5% inflation rate, this number is equivalent to a 5.0% real discount rate. See (1) for further explanation.

**Revenue Reductions and Avoided Costs:
Electric Dryers, Level 3, Base Case
(Millions of 1987 \$)**

Figure 8.3. Revenue Reductions and Avoided Costs for Electric Clothes Dryers

**Revenue Reductions and Avoided Costs:
Dishwashers, Level 3 (Millions of 1987 \$)**

Figure 8.4. Revenue Reductions and Avoided Costs for Dishwashers

**Revenue Reductions and Avoided Costs:
Electric Washers, Level 3 (Millions of 1987 \$)**

Figure 8.5. Revenue Reductions and Avoided Costs for Clothes Washers

**Table 8.1 Peak Demand Reductions (GW)
Electric Clothes Dryers**

Year	Peak Load	Peak Demand Savings			
		Level 1	Level 2	Level 3	Level 4
1992	8.9	0.0	0.0	0.0	0.0
1993	9.1	0.0	0.0	0.1	0.1
1994	9.2	0.1	0.1	0.1	0.2
1995	9.3	0.1	0.2	0.2	0.4
1996	9.4	0.2	0.3	0.3	0.5
1997	9.6	0.2	0.4	0.4	0.6
1998	9.7	0.3	0.4	0.5	0.8
1999	9.8	0.3	0.5	0.6	0.9
2000	9.9	0.3	0.6	0.7	1.1
2001	10.0	0.4	0.7	0.8	1.2
2002	10.1	0.4	0.7	0.9	1.3
2003	10.2	0.5	0.8	1.0	1.4
2004	10.3	0.5	0.9	1.0	1.5
2005	10.4	0.5	1.0	1.1	1.7
2006	10.5	0.5	1.0	1.1	1.7
2007	10.5	0.5	0.9	1.1	1.7
2008	10.5	0.5	0.9	1.1	1.7
2009	10.5	0.5	0.9	1.1	1.7
2010	10.5	0.5	0.8	1.0	1.7
2011	10.5	0.4	0.8	1.0	1.7
2012	10.5	0.4	0.7	0.9	1.7
2013	10.5	0.4	0.7	0.9	1.6
2014	10.5	0.4	0.6	0.8	1.6
2015	10.6	0.3	0.6	0.8	1.6

**Table 8.2 Capacity Savings (GW)
Electric Clothes Dryers**

Year	Capacity Savings			
	Level 1	Level 2	Level 3	Level 4
1992	0.0	0.0	0.0	0.0
1993	0.0	0.0	0.0	0.1
1994	0.1	0.1	0.1	0.2
1995	0.1	0.2	0.2	0.3
1996	0.2	0.3	0.4	0.6
1997	0.2	0.4	0.5	0.8
1998	0.3	0.5	0.6	0.9
1999	0.4	0.6	0.7	1.1
2000	0.4	0.7	0.8	1.3
2001	0.5	0.8	0.9	1.4
2002	0.5	0.9	1.0	1.6
2003	0.6	1.0	1.1	1.7
2004	0.6	1.1	1.2	1.9
2005	0.7	1.1	1.3	2.0
2006	0.7	1.2	1.4	2.0
2007	0.6	1.1	1.3	2.1
2008	0.6	1.1	1.3	2.1
2009	0.6	1.0	1.3	2.1
2010	0.6	1.0	1.2	2.0
2011	0.5	0.9	1.2	2.0
2012	0.5	0.9	1.1	2.0
2013	0.5	0.8	1.1	1.9
2014	0.4	0.7	1.0	1.9
2015	0.4	0.7	1.0	1.9

**Table 8.3 Peak Demand Reductions and Capacity Savings (GW)
Dishwashers**

Year	Peak Load	Peak Demand Reductions			Capacity Savings		
		Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
1992	3.1	0.0	0.0	0.0	0.0	0.0	0.0
1993	3.2	0.0	0.0	0.0	0.0	0.0	0.0
1994	3.2	0.0	0.1	0.1	0.0	0.1	0.1
1995	3.2	0.1	0.1	0.1	0.1	0.1	0.1
1996	3.3	0.1	0.1	0.2	0.1	0.2	0.2
1997	3.3	0.1	0.2	0.2	0.2	0.2	0.2
1998	3.4	0.2	0.2	0.2	0.2	0.3	0.3
1999	3.4	0.2	0.2	0.3	0.2	0.3	0.3
2000	3.4	0.2	0.3	0.3	0.3	0.3	0.4
2001	3.5	0.2	0.3	0.4	0.3	0.4	0.4
2002	3.5	0.2	0.3	0.4	0.3	0.4	0.4
2003	3.5	0.2	0.3	0.4	0.3	0.4	0.4
2004	3.5	0.2	0.3	0.4	0.3	0.4	0.5
2005	3.6	0.2	0.3	0.4	0.3	0.4	0.5
2006	3.6	0.2	0.3	0.4	0.2	0.4	0.5
2007	3.6	0.2	0.3	0.4	0.2	0.4	0.4
2008	3.6	0.2	0.3	0.4	0.2	0.3	0.4
2009	3.7	0.2	0.3	0.4	0.2	0.3	0.4
2010	3.7	0.2	0.3	0.4	0.2	0.3	0.4
2011	3.7	0.2	0.3	0.3	0.2	0.3	0.4
2012	3.7	0.1	0.3	0.3	0.2	0.3	0.4
2013	3.8	0.1	0.2	0.3	0.2	0.3	0.4
2014	3.8	0.1	0.2	0.3	0.1	0.3	0.4
2015	3.8	0.1	0.2	0.3	0.1	0.3	0.4

**Table 8.4 Peak Demand Reductions and Capacity Savings (MW)
Electric Clothes Washers**

Year	Peak Load	Peak Demand Reductions				Capacity Savings			
		Level 1	Level 2	Level 3	Level 4	Level 1	Level 2	Level 3	Level 4
1992	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1993	8.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0
1994	8.2	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.2
1995	8.3	0.1	0.2	0.3	0.3	0.1	0.2	0.2	0.2
1996	8.4	0.2	0.3	0.4	0.4	0.2	0.4	0.4	0.5
1997	8.4	0.2	0.4	0.5	0.5	0.3	0.5	0.5	0.6
1998	8.5	0.3	0.5	0.5	0.6	0.3	0.5	0.7	0.7
1999	8.6	0.3	0.5	0.6	0.7	0.4	0.6	0.8	0.8
2000	8.6	0.4	0.6	0.7	0.8	0.4	0.7	0.8	0.9
2001	8.7	0.4	0.7	0.8	0.9	0.5	0.8	0.9	1.0
2002	8.8	0.4	0.7	0.8	0.9	0.5	0.8	1.0	1.1
2003	8.8	0.4	0.7	0.8	0.9	0.5	0.8	1.0	1.1
2004	8.8	0.4	0.7	0.9	0.9	0.5	0.9	1.0	1.1
2005	8.9	0.4	0.7	0.9	1.0	0.5	0.9	1.1	1.2
2006	8.9	0.4	0.7	0.9	1.0	0.5	0.9	1.1	1.2
2007	9.0	0.4	0.7	0.9	1.0	0.5	0.9	1.1	1.2
2008	9.0	0.4	0.7	0.9	1.0	0.5	0.9	1.1	1.2
2009	9.0	0.4	0.7	0.9	1.0	0.5	0.9	1.1	1.2
2010	9.1	0.4	0.7	0.9	1.0	0.5	0.9	1.0	1.1
2011	9.1	0.4	0.7	0.9	0.9	0.5	0.8	1.0	1.1
2012	9.2	0.4	0.7	0.8	0.9	0.4	0.8	1.0	1.1
2013	9.2	0.4	0.7	0.8	0.9	0.4	0.8	1.0	1.1
2014	9.3	0.3	0.6	0.8	0.9	0.4	0.8	1.0	1.1
2015	9.3	0.3	0.6	0.8	0.9	0.4	0.8	0.9	1.0

Table 8.5 Net Revenue Losses
Clothes Dryers
(Million 1987 Dollars)

Year	Level 1	Level 2	Level 3	Level 4
1992	0	0	0	0
1993	7	12	15	23
1994	17	29	35	54
1995	27	47	55	85
1996	34	60	71	108
1997	43	75	88	135
1998	51	89	105	158
1999	58	102	119	180
2000	64	112	132	198
2001	70	122	143	214
2002	76	132	154	230
2003	80	139	163	242
2004	84	146	170	254
2005	86	151	176	261
2006	84	146	172	259
2007	78	136	162	249
2008	72	126	152	240
2009	66	116	142	230
2010	60	105	131	218
2011	54	95	120	206
2012	48	84	109	192
2013	43	74	98	179
2014	37	65	88	165
2015	32	56	78	153
Total	1270	2219	2676	4232

**Table 8.6 Net Revenue Losses
Dishwashers
(Million 1987 Dollars)**

Year	Level 1	Level 2	Level 3
1992	0	0	0
1993	4	5	7
1994	10	14	16
1995	16	22	25
1996	19	27	31
1997	23	33	38
1998	27	39	45
1999	30	43	50
2000	32	47	54
2001	32	47	54
2002	29	46	52
2003	27	44	51
2004	24	42	49
2005	21	39	46
2006	18	36	42
2007	15	33	39
2008	13	30	35
2009	10	27	32
2010	8	24	28
2011	6	22	25
2012	4	19	22
2013	2	17	19
2014	1	15	16
2015	0	13	13
Total	371	684	789

**Table 8.7 Net Revenue Losses
Electric Clothes Washers
(Million 1987 Dollars)**

Year	Level 1	Level 2	Level 3	Level 4
1992	0	0	0	0
1993	6	10	12	14
1994	14	22	28	31
1995	20	32	41	46
1996	24	38	49	55
1997	28	45	59	67
1998	31	50	67	76
1999	34	55	73	83
2000	35	58	78	88
2001	35	58	80	91
2002	33	55	78	89
2003	31	51	74	85
2004	27	46	69	80
2005	24	41	64	74
2006	20	35	57	67
2007	17	30	51	60
2008	13	23	43	52
2009	10	17	37	45
2010	6	11	29	36
2011	3	5	22	29
2012	-1	-1	15	21
2013	-3	-6	9	14
2014	-6	-11	3	7
2015	-9	-16	-4	0
Total	392	648	1034	1210

**Table 8.8 Present Value of Revenue Losses
Electric Clothes Dryers
(Million 1987 Dollars)**

Regulatory Lag	Level 1	Level 2	Level 3	Level 4
None	0	0	0	0
1993-1997	84	147	173	266
1993-2015	556	972	1162	1811

**Table 8.9 Present Value of Revenue Losses
Dishwashers
(Million 1987 Dollars)**

Regulatory Lag	Level 1	Level 2	Level 3
None	0	0	0
1993-1997	47	67	77
1993-2015	186	318	365

**Table 8.10 Present Value of Revenue Losses
Electric Clothes Washers
(Million 1987 Dollars)**

Regulatory Lag	Level 1	Level 2	Level 3	Level 4
None	0	0	0	0
1993-1997	61	96	125	140
1993-2015	207	337	510	586

**Table 8.11 Peak Demand Reductions and Capacity Savings (GW)
Electric Dryers (Sensitivity Cases 4, 7, 8)**

Year	Peak Demand Reductions			Capacity Savings		
	Case 4	Case 7	Case 8	Case 4	Case 7	Case 8
1992	0.0	0.0	0.0	0.0	0.0	0.0
1995	0.2	0.1	0.0	0.2	0.1	0.0
2000	0.6	0.1	0.0	0.7	0.1	0.0
2005	0.9	0.1	0.0	1.1	0.1	0.0
2010	1.2	0.0	0.0	1.5	0.0	0.0
2015	1.4	0.0	0.0	1.7	0.0	0.0

**Table 8.12 Peak Demand Reductions and Capacity Savings (GW)
Dishwashers (Sensitivity Cases 4, 7, 8)**

Year	Peak Demand Reductions			Capacity Savings		
	Case 4	Case 7	Case 8	Case 4	Case 7	Case 8
1992	0.0	0.0	0.0	0.0	0.0	0.0
1995	0.1	0.1	0.0	0.1	0.1	0.0
2000	0.3	0.1	0.1	0.4	0.1	0.2
2005	0.5	0.1	0.2	0.6	0.1	0.3
2010	0.6	0.1	0.3	0.8	0.1	0.3
2015	0.7	0.0	0.3	0.8	0.0	0.3

**Table 8.13 Peak Demand Reductions and Capacity Savings (GW)
Electric Clothes Washers (Sensitivity Cases 4, 7, 8)**

Year	Peak Demand Reductions			Capacity Savings		
	Case 4	Case 7	Case 8	Case 4	Case 7	Case 8
1992	0.0	0.0	0.0	0.0	0.0	0.0
1995	0.3	0.4	0.1	0.2	0.3	0.1
2000	0.7	0.8	0.3	0.9	1.0	0.4
2005	1.0	0.8	0.5	1.2	1.0	0.6
2010	1.1	0.6	0.6	1.3	0.8	0.7
2015	1.1	0.4	0.7	1.3	0.5	0.8

**Table 8.14 Present Value of Revenue Losses
Electric Dryers (Sensitivity Cases 4, 7, 8)
(Million 1987 Dollars)**

Regulatory Lag	Case 4	Case 7	Case 8
None	0	0	0
1993-1997	146	46	0
1993-2015	1120	115	0

**Table 8.15 Present Value of Revenue Losses
Dishwashers (Sensitivity Cases 4, 7, 8)
(Million 1987 Dollars)**

Regulatory Lag	Case 4	Case 7	Case 8
None	0	0	0
1993-1997	81	43	36
1993-2015	452	117	210

**Table 8.16 Present Value of Revenue Losses
Electric Clothes Washers (Sensitivity Cases 4, 7, 8)
(Million 1987 Dollars)**

Regulatory Lag	Case 4	Case 7	Case 8
None	0	0	0
1993-1997	127	192	52
1993-2015	542	798	251

APPENDIX A. ENERGY USE AND COST DATA

This appendix presents detailed energy use and manufacturer cost data for the three product types. Sections A.1 and A.3 show the energy use for various models of dishwashers and clothes washers, respectively. The data are from manufacturer's submission to the Federal Trade Commission (FTC). They include the electrical energy for the appliance motors and heaters (where applicable) and the electricity and gas used in providing the hot water.

Manufacturer cost data for design options of product classes are presented in Sections A.2 (dishwashers), A.4 (clothes washers), and A.5 (clothes dryers). The cost data are disaggregated into labor, materials, purchased parts, and tooling.

Appendix A.1
FTC DISHWASHER ENERGY USE DATA

Company	Model	Class	# of Models	Machine Elec. kWh/cycle	Elec Water Heating kWh/cycle	Total Elec. kWh/cycle	Energy Factor 1/kWh	Water Cons. Gal	Gas \$/year	Elec \$/year
GE	GE14795	Std	1	0.660	2.460	3.120	0.321	11.39	36	78
KitchenAid	KUD822	Std	1	0.391	2.634	3.000	0.333	12.19	31	75
Maytag	MD84	Std	1	0.580	2.450	3.030	0.330	11.34	34	75
Maytag	MD83	Std	16	0.450	2.450	2.900	0.345	11.34	31	72
Whirlpool	156958	Std	11	0.846	2.354	3.200	0.313	10.90	36	75
Whirlpool	WU3000V	Std	6	0.731	2.354	3.085	0.324	10.90	33	73
Whirlpool	WU3000V	Std	6	0.731	2.354	3.085	0.324	10.90	33	73
Whirlpool	DP8350XV	Std	1	0.663	2.354	3.017	0.331	10.90	32	71
Whirlpool	DU5000XW	Std	5	0.592	2.197	2.789	0.359	10.17	29	66
Whirlpool	WU3000W	Std	2	0.592	2.197	2.789	0.359	10.17	29	66
Whirlpool	GDU8700XT	Std	1	0.653	1.884	2.537	0.394	8.72	28	59
Whirlpool	DU7600XS	Std	11	0.645	1.884	2.529	0.395	8.72	28	59
WCI	Sears14380	WH-Compact	14	0.723	1.260	1.983	0.504	7.50	28	49
GE	GSD1200L02	WH-std	1	0.990	2.070	3.060	0.327	12.32	41	76
GE	DU4000B	WH-std	1	0.650	2.210	2.860	0.350	13.15	34	71
GE	DU2C	WH-std	9	0.734	2.114	2.848	0.351	12.58	35	71
GE	GSC402	WH-std	1	0.860	1.930	2.790	0.358	11.49	37	69
GE	DU6000B	WH-std	1	0.720	2.070	2.790	0.358	12.32	36	69
GE	GSD500L	WH-std	3	0.720	2.070	2.790	0.358	12.32	35	69
GE	GSD1000L	WH-std	5	0.770	2.000	2.770	0.361	11.90	35	69
GE	DU5000B	WH-std	1	0.690	2.050	2.740	0.365	12.20	34	70
GE	GSD990L	WH-std	2	0.690	2.040	2.730	0.366	12.14	34	68
GE	PSD460K	WH-std	1	0.820	1.820	2.640	0.379	10.83	36	68
GE	GSD580K	WH-std	13	0.660	1.970	2.630	0.380	11.73	34	68
GE	GSD2200L	WH-std	5	0.820	1.790	2.610	0.383	10.65	36	66
GE	DU65C	WH-std	2	0.720	1.880	2.600	0.385	11.19	33	65
GE	GSD2790L	WH-std	7	0.785	1.790	2.575	0.388	10.65	36	66
GE	HDA850G	WH-std	1	0.840	1.660	2.500	0.400	9.88	36	66
GE	HDA467K	WH-std	9	0.860	1.630	2.490	0.402	9.70	36	67
GE	GSC452	WH-std	4	0.780	1.690	2.470	0.405	10.06	33	61
GE	HDA787K	WH-std	2	0.870	1.590	2.460	0.407	9.46	36	66
GE	HD110C	WH-std	1	0.670	1.770	2.440	0.410	10.54	31	62
GE	HDB827G	WH-std	2	0.690	1.740	2.430	0.412	10.36	31	62
GE	HDA787	WH-std	2	0.860	1.530	2.390	0.418	9.11	35	62
In-Sink-Erat.	Classic-Supre	WH-std	1	0.626	1.915	2.540	0.394	11.40	31	63
In-Sink-Erat.	Classic	WH-std	1	0.622	1.556	2.190	0.457	9.26	28	54
KitchenAid	KUD22S	WH-std	1	0.825	1.676	2.501	0.400	9.98	34	62
KitchenAid	KUD21S	WH-std	1	0.884	1.616	2.450	0.408	9.62	35	62
KitchenAid	KUD22I	WH-std	1	0.665	1.796	2.450	0.408	10.69	31	61
KitchenAid	KUD21I	WH-std	1	0.644	1.736	2.370	0.422	10.33	30	59
KitchenAid	KUD22P	WH-std	1	0.583	1.676	2.240	0.446	9.98	28	56
Miele	G 572u	WH-std	5	0.900	1.470	2.370	0.422	7.66	34	59
WCI	DW6600F1	WH-std	2	0.804	2.167	2.971	0.337	12.90	37	74
WCI	Sears14030	WH-std	34	0.735	2.191	2.916	0.343	13.04	36	72
WCI	Sears14095	WH-std	10	0.629	2.251	2.880	0.347	13.40	34	71
WCI	Sears14860	WH-std	3	0.813	1.915	2.728	0.367	11.40	36	68
WCI	Sears14680	WH-std	15	0.743	1.935	2.678	0.373	11.52	34	66
WCI	Sears14690	WH-std	2	0.632	1.939	2.571	0.389	11.54	31	64
WCI	DW3300D2	WH-std	5	0.796	1.645	2.441	0.410	9.79	33	61
WCI	SU24D5	WH-std	4	0.785	1.631	2.417	0.414	9.71	33	60
WCI	DWF600E1	WH-std	14	0.730	1.647	2.377	0.421	9.81	31	59
WCI	DW2200D2	WH-std	3	0.697	1.609	2.307	0.434	9.58	30	57
WCI	DW1100DW2	WH-std	16	0.695	1.603	2.298	0.435	9.54	30	57
WCI	DU5409	WH-std	3	0.700	1.529	2.229	0.449	9.10	30	55
WCI	DU5406	WH-std	8	0.639	1.530	2.169	0.461	9.11	28	54

APPENDIX A.2

The following tables show the manufacturer costs for several design options for dishwashers. Three classes of dishwashers are considered: standard, standard water heating and compact. Four design options are presented. The total incremental manufacturer cost is disaggregated into four subcategories: labor cost, material cost, purchased parts and tooling cost. The total costs at each design level are cumulative, that is, for level 2, the \$11.50 cost increase over the baseline is for both the reduction in water use and the improved motor efficiency. The cost data for the standard dishwashers were provided by dishwasher manufacturers. The cost data for the standard dishwasher were extrapolated to the other two classes.

APPENDIX A.2

Manufacturer Cost Data * - Standard Dishwasher, 115 V.

Level	Design Option	Labor	Material	Purchased Parts	Tooling	Total ** Inc. Cost	Total Cost	Confidence (±%)
0	Baseline						150	20%
1	Reduce Water Use	0.75	6	0	0.75	7.5	157.5	33%
2	1 + Imp. Motor Eff.	0	0	4	0	4	161.5	50%
3	2 + Booster Heater	1	0	8	1	10	171.5	33%
4	3 + Imp. Fill Control	0	0	8	0	8	179.5	50%
5	1 + Booster Heater	1	0	8	1	10	167.5	33%
6	5 + Imp. Motor Eff.	0	0	4	0	4	171.5	50%
7	6 + Imp. Fill Control	0	0	8	0	8	179.5	50%

Manufacturer Cost Data * - Standard Water Heating Dishwasher, 115 V.

Level	Design Option	Labor	Material	Purchased Parts	Tooling	Total ** Inc. Cost	Total Cost	Confidence (±%)
0	Baseline						160	20%
1	Reduce Water Use	0.75	6	0	0.75	7.5	167.5	33%
2	1 + Reduce Booster	0	0	0	2	2	169.5	33%
3	2 + Imp. Motor Eff.	0	0	4	0	4	173.5	50%
4	3 + Imp. Fill Control	0	0	8	0	8	181.5	50%

Manufacturer Cost Data * - Compact Dishwasher, 115 V.

Level	Design Option	Labor	Material	Purchased Parts	Tooling	Total ** Inc. Cost	Total Cost	Confidence (±%)
0	Baseline						130	20%
1	Improv. Food Filter	0.75	6	0	0.75	7.5	137.5	33%
2	1 + Reduce Booster	0	0	0	2	2	139.5	33%
3	2 + Imp. Motor Eff.	0	0	4	0	4	143.5	50%
4	3 + Imp. Fill Control	0	0	8	0	8	151.5	50%

* Costs are in 1988 \$ and are for one unit.

** Total Incremental Cost is always relative to the preceding design option.

Appendix A.3
FTC CLOTHES WASHER ENERGY USE DATA

Company	Model	Class	# of Models	Machine Electric kWh/cycle	Electric Heating Kwh/cycle	Total Electric kWh/cycle	Gas Water Heating BTU/cycle	Capacity ft3	Energy Factor ft3/kWh/cyc	Gas \$/yr	Elec \$/yr
Whirlpool		Standard	7	0.21	1.89	2.10	8,560			27	70
Whirlpool		Standard	2	0.22	2.98	3.20	13,500			39	107
Whirlpool		Standard	24	0.22	1.93	2.16	8,810			28	72
Whirlpool		Standard	8	0.22	2.32	2.54	10,480			32	85
Whirlpool		Standard	1	0.19	1.93	2.12	8,810			27	71
Whirlpool		Standard	2	0.21	2.15	2.37	9,780			30	79
Whirlpool		Standard	2	0.23	2.19	2.41	9,930			31	81
Whirlpool		Standard	7	0.22	3.55	3.76	16,030			45	126
Whirlpool		Standard	1	0.21	4.03	4.24	18,375			50	142
Whirlpool		Standard	3	0.31	3.55	3.85	16,290			48	129
Whirlpool		Standard	3	0.26	3.60	3.85	16,429			47	129
Whirlpool		Standard	5	0.23	3.68	3.90	16,742			47	131
Whirlpool		Standard	1	0.23	4.08	4.28	18,500			51	144
Whirlpool		Standard	1	0.22	2.32	2.55	10,530			32	85
Whirlpool		Standard	1	0.22	2.41	2.64	10,970			33	88
Whirlpool		Standard	2	0.23	3.68	3.89	16,605			47	131
Whirlpool		Standard	11	0.23	2.28	2.52	10,370			32	84
Whirlpool		Standard	10	0.23	2.76	3.00	12,590			37	100
Whirlpool		Standard	2	0.24	3.29	3.52	14,870			43	118
Whirlpool		Standard	3	0.25	2.32	2.57	10,630			33	86
Whirlpool		Standard	5	0.25	3.73	3.99	17,151			48	133
Whirlpool		Standard	3	0.25	3.73	3.98	16,992			48	133
Whirlpool		Standard	5	0.24	2.81	3.03	12,740			38	102
Whirlpool		Standard	1	0.18	2.46	2.62	10,980			32	88
Whirlpool	LC4500XS/XT	Compact	2	0.23	1.36	1.60	6,300	1.50	0.94	22	53
Whirlpool	LC4900XS/XT	Compact	2	0.20	2.37	2.56	10,720	1.50	0.59	32	86
Whirlpool	KELC500S/T	Compact	2	0.23	1.45	1.68	6,720	1.50	0.89	23	56
Whirlpool	LT4900XS	Compact	1	0.23	1.45	1.68	6,720	1.50	0.89	23	56
Whirlpool	LT5000XS	Compact	1	0.23	1.45	1.68	6,720	1.50	0.89	23	56
Whirlpool	LT5004XS	Compact	1	0.23	1.45	1.68	6,720	1.50	0.89	23	56
Whirlpool	LT5100XS	Compact	1	0.23	1.45	1.68	6,720	1.50	0.89	23	56
Whirlpool	2646711	Compact	1	0.22	2.32	2.54	10,650	1.50	0.59	32	85
Whirlpool	2648701	Compact	1	0.22	2.32	2.54	10,650	1.50	0.59	32	85
Whirlpool	2644181	Compact	1	0.19	1.93	2.12	8,740	1.50	0.71	27	71
Whirlpool	2696751	Compact	1	0.19	1.93	2.12	8,740	1.50	0.71	27	71
Whirlpool	2644191	Compact	1	0.19	1.93	2.12	8,740	1.50	0.71	27	71
Whirlpool	LA5300XT	Standard	1	0.22	1.93	2.16	8,810	2.45	1.13	28	72
Whirlpool	LA5400XT	Standard	1	0.22	1.93	2.16	8,810	2.45	1.13	28	72
Whirlpool	LA5320XT	Standard	1	0.22	1.93	2.16	8,810	2.45	1.13	28	72
Whirlpool	LA5700XT	Standard	1	0.25	2.32	2.57	10,630	2.45	0.95	33	86
Whirlpool	LA5720XT	Standard	1	0.25	2.32	2.57	10,630	2.45	0.95	33	86
Whirlpool	LA3400XT	Standard	1	0.23	2.19	2.41	9,930	2.45	1.02	31	81
Whirlpool	LA4800XT	Standard	1	0.22	1.93	2.16	8,810	2.45	1.13	28	72
Whirlpool	LA5420XT	Standard	1	0.22	1.93	2.16	8,810	2.45	1.13	28	72
Whirlpool	LA6300XT	Standard	1	0.25	2.32	2.57	10,630	2.45	0.95	33	86
Whirlpool	LA5380XT	Standard	1	0.23	2.28	2.52	10,370	3.05	1.21	32	84
Whirlpool	LA5580XT	Standard	1	0.23	2.28	2.52	10,370	3.05	1.21	32	84
Whirlpool	LA5800XT	Standard	1	0.24	2.81	3.03	12,740	3.05	1.01	38	102
Whirlpool	LA7800XT	Standard	1	0.26	3.60	3.85	16,429	3.05	0.79	47	129
Whirlpool	LA8800XT	Standard	1	0.26	3.60	3.85	16,429	3.05	0.79	47	129
Whirlpool	LA9800XT	Standard	1	0.24	3.29	3.52	14,870	3.05	0.87	43	118
Whirlpool	KAW700T	Standard	1	0.23	3.03	3.25	13,730	3.05	0.94	40	109
Whirlpool	KAW800T	Standard	1	0.21	3.86	4.05	17,380	3.05	0.75	48	136
Whirlpool	KAW900T	Standard	1	0.25	3.81	4.05	17,340	3.05	0.75	49	136
Whirlpool	KAW550V	Standard	1	0.18	2.54	2.77	11,470	3.05	1.10	33	91
Whirlpool	KAW650T	Standard	1	0.24	2.54	2.77	11,550	3.05	1.10	35	93
Whirlpool	KAW750V	Standard	1	0.24	3.29	3.53	14,990	3.05	0.86	43	118
Whirlpool	KAW850V	Standard	1	0.23	4.17	4.39	19,010	3.05	0.69	52	147
WCI	Westinghouse	Std./Front	3	0.12	0.57	0.6988		2.25	3.22	10	23
WCI	Gibson	Std./Front	1	0.12	0.57	0.6988		2.25	3.22	10	23
WCI	Westinghouse	Std./Front	1	0.10	0.61	0.7180		2.25	3.13	10	24
WCI	Montgomery	Std./Front	1	0.25	0.92	1.1685		2.25	1.93	18	39
WCI	Westinghouse	Standard	1	0.21	2.46	2.6495		2.51	0.95	33	89
WCI	Montgomery	Standard	1	0.21	2.46	2.6495		2.51	0.95	33	89
WCI	Westinghouse	Standard	8	0.20	2.02	2.2125		2.48	1.12	28	74

Company	Model	Class	# of Models	Machine Electric kWh/cycle	Elc Water Heating Kwh/cycle	Total Electric kWh/cycle	Gas Water Heating BTU/cycle	Capacity ft3	Energy Factor ft3/kWh/cyc	Gas \$/yr	Elec \$/yr
WCI	Montgomery	Standard	4	0.20	2.02	2.2125		2.48	1.12	28	74
WCI	Tappan	Standard	3	0.20	2.02	2.2125		2.48	1.12	28	74
WCI	Montgomery	Standard	2	0.26	2.08	2.335	9,468	2.51	1.07	30	75
WCI	Kelvinator	Standard	4	0.26	2.08	2.335	9,468	2.51	1.07	30	75
WCI	Gibson	Standard	3	0.26	2.08	2.335	9,468	2.51	1.07	30	75
WCI	Philco	Standard	3	0.26	2.08	2.335	9,468	2.51	1.07	30	75
WCI	Frigidaire	Standard	5	0.26	2.08	2.335	9,468	2.51	1.07	30	75
WCI	Montgomery	Standard	1	0.26	2.18	2.441	9,857	2.51	1.03	31	78
WCI	Kelvinator	Standard	4	0.26	2.18	2.441	9,857	2.51	1.03	31	78
WCI	Gibson	Standard	1	0.26	2.18	2.441	9,857	2.51	1.03	31	78
WCI	Westinghouse	Standard	1	0.26	2.18	2.441	9,857	2.51	1.03	31	78
WCI	Frigidaire	Standard	12	0.26	2.18	2.441	9,857	2.51	1.03	31	78
WCI	Kelvinator	Standard	1	0.26	2.55	2.811	11,543	2.51	0.89	35	90
WCI	Frigidaire	Standard	1	0.26	2.55	2.811	11,543	2.51	0.89	35	90
WCI	Kelvinator	Compact	1	0.28	3.15	3.435	14,381	1.40	0.41	42	110
WCI	Montgomery	Compact	1	0.23	2.55	2.788	11,593	1.40	0.50	34	89
WCI	Kelvinator	Compact	1	0.23	2.55	2.788	11,593	1.40	0.50	34	89
WCI	Westinghouse	Compact	1	0.23	2.55	2.788	11,593	1.40	0.50	34	89
WCI	GE	Compact	4	0.23	2.55	2.788	11,593	1.40	0.50	34	89
WCI	Frigidaire	Compact	1	0.23	2.55	2.788	11,593	1.40	0.50	34	89
WCI	Montgomery	Compact	1	0.20	1.30	1.498	5,773	1.40	0.93	20	48
WCI	Kelvinator	Compact	2	0.20	1.30	1.498	5,773	1.40	0.93	20	48
WCI	Gibson	Compact	1	0.20	1.30	1.498	5,773	1.40	0.93	20	48
WCI	Westinghouse	Compact	1	0.20	1.30	1.498	5,773	1.40	0.93	20	48
WCI	GE	Compact	1	0.20	1.30	1.498	5,773	1.40	0.93	20	48
WCI	Tappan	Compact	1	0.25	1.34	1.591	6,196	1.40	0.88	22	51
WCI	Westinghouse	Compact	2	0.25	1.34	1.591	6,196	1.40	0.88	22	51
WCI	Philco	Compact	1	0.25	1.34	1.591	6,196	1.40	0.88	22	51
WCI	Frigidaire	Compact	6	0.25	1.34	1.591	6,196	1.40	0.88	22	51
WCI	Tappan	Compact	2	0.22	1.53	1.747	7,029	1.40	0.80	23	56
GE		Standard	2	0.17	3.10	3.20		2.70	0.84	38	105
GE		Standard	3	0.20	2.92	3.05		2.70	0.89	37	100
GE		Standard	2	0.20	2.92	2.98		2.70	0.91	37	100
GE		Standard	1	0.20	2.92	3.03		2.70	0.89	37	100
GE		Standard	3	0.22	2.69	2.89		2.70	0.93	35	93
GE		Standard	1	0.20	2.55	2.69		2.70	1.00	33	88
GE		Standard	5	0.17	2.46	2.54		2.70	1.06	31	84
GE		Standard	9	0.18	2.41	2.48		2.70	1.09	31	83
GE		Standard	1	0.18	2.41	2.43		2.70	1.11	31	83
GE		Standard	1	0.27	2.22	2.47		2.30	0.93	32	80
GE		Standard	2	0.16	2.27	2.35		2.70	1.15	29	78
GE		Standard	8	0.20	2.18	2.32		2.30	0.99	29	76
GE		Standard	3	0.18	2.13	2.14		2.70	1.26	28	74
GE		Standard	1	0.27	1.85	2.07		2.30	1.11	28	68
GE		Standard	3	0.21	1.85	2.01		2.30	1.14	26	66
Norge	LWF18-1	Standard	14	0.277	3.084	3.361	14,032	3.00	0.89	41	108
Norge	LWF20-2	Standard	11	0.277	2.660	2.937	12,144	3.00	1.02	37	94
Norge	LWF20-4	Standard	21	0.290	2.870	3.160	13,056	3.00	0.95	39	101
Norge	LWF20-8	Standard	28	0.284	3.510	3.794	15,968	3.00	0.79	46	122
Norge	LNC6105A	Compact	2	0.181	1.384	1.565	6,297	1.40	0.89	20	50
Maytag		Standard	2	0.14	1.85	2.01		2.54	1.26	24	64
Maytag		Standard	9	0.16	1.81	1.97		2.54	1.29	24	63
Maytag		Standard	11	0.16	2.08	2.25		2.93	1.30	27	72
Maytag		Standard	1	0.13	2.97	3.08		2.93	0.95	35	99
Maytag		Standard	2	0.14	2.55	2.67		2.93	1.10	31	86
Maytag		Standard	1	0.13	1.90	2.02		2.54	1.26	24	65
Maytag		Standard	2	0.24	2.04	2.29		2.93	1.28	29	73
Maytag		Standard	1	0.13	3.06	3.18		2.93	0.92	36	102
Speed Queen		Standard	1	0.269	2.348	2.617	10,676	2.52	0.96	33	84
Speed Queen		Standard	39	0.277	2.860	3.137	13,003	2.52	0.80	39	100
Speed Queen		Standard	31	0.260	1.923	2.183	8,760	2.52	1.15	28	70
Speed Queen		Standard	1	0.249	1.810	2.060	8,234	2.52	1.22	27	66
Speed Queen		Standard	23	0.269	2.348	2.617	10,676	2.52	0.96	33	84
Speed Queen		Standard	5	0.260	1.923	2.183	8,740	2.52	1.15	28	70
Speed Queen		Standard	14	0.253	2.660	2.910	12,101	2.52	0.87	36	93
Speed Queen		Standard	2	0.274	1.985	2.259	9,025	2.52	1.12	29	72

Company	Model	Class	# of Models	Machine Electric kWh/cycle	Elc Water Heating kWh/cycle	Total Electric kWh/cycle	Gas Water Heating BTU/cycle	Capacity ft3	Energy Factor ft3/kWh/cyc	Gas \$/yr	Elec \$/yr
Speed Queen		Standard	1	0.260	1.834	2.097	8,339	2.52	1.20	27	67
Speed Queen		Standard	2	0.275	2.649	2.924	12,051	2.52	0.86	36	94
Speed Queen		Standard	2	0.257	2.250	2.507	10,236	2.52	1.01	32	80

APPENDIX A.4

The following tables show the manufacturing costs for several design options for clothes washers. Two classes of top loading clothes washers are considered: compact, and standard. Six design options are presented. The total incremental manufacturing cost is disaggregated into four subcategories: labor, materials, purchased parts and tooling. The total costs at each design level are cumulative. For example, for level 6, the \$111 cost increase over the baseline is for elimination of the warm/warm setting option and the warm rinse option, and the conversion to a horizontal axis washer. The cost data for three of the standard clothes washer options (improved motor efficiency, plastic tub, thermostatic mixing valves) were provided by clothes washer manufacturers. The cost data for standard washer were extrapolated to the compact class.

APPENDIX A.4
Manufacturer Cost Data^{*} - Compact Clothes Washer, Top Loading

Level	Design Option	Labor	Material	Purchased Parts	Tooling	Total ^{**} Inc. Cost	Total Cost	Confidence (±%)
0	Baseline						155	15%
1	Elim. W/W Setting	0	0	0	0.5	0.5	155.5	20%
2	Elim. Warm Rinse	0	0	0	0.5	0.5	156	20%
3	2 + Imp. Motor Eff.	0	0	7.5	0	7.5	163.5	20%
4	3 + Plastic Tub	0	0	5	1	6	169.5	50%
5	4 + TMV***	0.6	0	12	0.4	13	182.5	50%
6	2 + Horizontal Axis	3	3	4	100	110	266	20%
7	6 + Plastic Tub	0	0	5	1	6	272	50%
8	7 + TMV***	0.6	0	12	0.4	13	285	50%

Manufacturer Cost Data^{*} - Clothes Washer, Top Loading, Standard Capacity

Level	Design Option	Labor	Material	Purchased Parts	Tooling	Total ^{**} Inc. Cost	Total Cost	Confidence (±%)
0	Baseline						200	15%
1	Elim. W/W Setting	0	0	0	0.5	0.5	200.5	20%
2	Elim. Warm Rinse	0	0	0	0.5	0.5	201	20%
3	2 + Imp. Motor Eff.	0	0	7.5	0	7.5	208.5	20%
4	3 + Plastic Tub	0	0	5	1	6	214.5	50%
5	4 + TMV**	0.6	0	12	0.4	13	227.5	50%
6	2 + Horizontal Axis	3	3	4	100	110	311	20%
7	6 + Plastic Tub	0	0	5	1	6	317	50%
8	7 + TMV***	0.6	0	12	0.4	13	330	50%

* Costs are in 1988 \$ and are for one unit.

** Total Incremental Cost is always relative to the preceding design option.

*** Thermostatic Mixing Valves

APPENDIX A.5

The following tables show the manufacturing costs for design options for clothes dryers. Four classes of clothes dryers are considered: electric standard, electric compact 110 V, electric compact 240 V and gas standard. Five design options are presented. The total incremental manufacturer cost is disaggregated into four subcategories: labor, materials, purchased parts and tooling. The total costs at each design level are cumulative. For level 2, the \$14.6 cost increase over the baseline is for both the automatic termination option and the addition of insulation. The cost data for three of the standard electric dryer options (automatic termination, added insulation, recycle exhaust) were provided by dryer manufacturers. The cost data for the standard clothes dryer were extrapolated to the other three classes.

APPENDIX A.5

Manufacturer Cost Data * - Compact Clothes Dryer (110V)

Level	Design Option	Labor	Material	Purchased Parts	Tooling	Total ** Inc. Cost	Total Cost	Confidence (±%)
0	Baseline						125	20%
1	Automatic Term.	0.5	0	7	0.5	8	133	20%
2	1 + Add 1" Insul.	0.5	5.4	0	0.7	6.6	139.6	25%
3	2 + Recycle exhaust	3	0	21	6	30	169.6	50%
4	2 + Microwave	1	1	84	1.5	87.5	227.1	50%
5	2 + Heat Pump	3	1	143	3	150	289.6	50%

Manufacturer Cost Data * - Compact Clothes Dryer (240V)

Level	Design Option	Labor	Material	Purchased Parts	Tooling	Total ** Inc. Cost	Total Cost	Confidence (±%)
0	Baseline						140	20%
1	Automatic Term.	0.5	0	7	0.5	8	148	20%
2	1 + Add 1" Insul.	0.5	5.4	0	0.7	6.6	154.6	25%
3	2 + Recycle exhaust	3	0	21	6	30	184.6	50%
4	2 + Microwave	1	1	84	1.5	87.5	242.1	50%
5	2 + Heat Pump	3	1	143	3	150	304.6	50%

Manufacturer Cost Data * - Electric Standard Clothes Dryer

Level	Design Option	Labor	Material	Purchased Parts	Tooling	Total ** Inc. Cost	Total Cost	Confidence (±%)
0	Baseline						150	20%
1	Automatic Term.	0.5	0	7	0.5	8	158	20%
2	1 + Add 1" Insul.	0.5	5.4	0	0.7	6.6	164.6	25%
3	2 + Recycle exhaust	3	0	21	6	30	194.6	50%
4	2 + Microwave	1	1	84	1.5	87.5	252.1	50%
5	2 + Heat Pump	3	1	143	3	150	314.6	50%

Manufacturer Cost Data * - Gas Clothes Dryer

Level	Design Option	Labor	Material	Purchased Parts	Tooling	Total ** Inc. Cost	Total Cost	Confidence (±%)
0	Baseline						170	20%
1	Automatic Term.	0.5	0	7	0.5	8	178	20%
2	1 + Add 1" Insul.	0.5	5.4	0	0.7	6.6	184.6	25%
3	2 + Recycle exhaust	3	0	21	6	30	214.6	50%

* Costs are in 1988 \$ and are for one unit.

** Total Incremental Cost is always relative to the preceding design option.

APPENDIX B. LBL RESIDENTIAL ENERGY MODEL

B.1 OVERVIEW

The LBL-REM provides projections of the important characteristics of the residential appliance market. The LBL-REM utilizes a data base 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 model provides.

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 2015. 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:

$$Q_t^{ikm} = STOKC_t^m \times C_t^{ikm} \times EU_t^{ikm} \times U_t^{ik} \times TI_t^{ikm}$$

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, 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, and by improving the efficiency of their equipment, e.g., purchasing a water heater with more jacket insulation. Thus, the elasticity of demand for a particular fuel with respect to the price of that fuel can be 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}):

$$E = E_u + E_e + E_{ms}$$

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.2 HOUSING

The updated housing submodel includes several features:

- 1) The model uses 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) The new method utilizes population projections for states by house type. This feature, combined with climate data, permits estimation of the fraction of households with heat loads that could be met by small gas furnaces.
- 3) Projections of the numbers of people in each age group in future years are used to project changes in the distribution of house types.

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 which include single-family detached, single-family attached, multifamily with five or more units per building, and mobile homes. (1) 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. (2) 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.

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, including economic factors. (3)

B.3 BUILDING SHELL THERMAL INTEGRITY

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

$$\frac{TIN}{TIN_0} = \frac{TINF}{TIN_0} + \left[\frac{TBETA}{TBETA + C} \right]^{TALFA} \left[1 - \frac{TINF}{TIN_0} \right]$$

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	.280	12	9600
Multifamily	.434	4	1886.7
Mobile homes	.440	9	2290.9

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 dishwashers, clothes washers, and clothes dryers. The only interaction between energy consumption of these products and the building shell characteristics is through internal loads generated by these products, or by water heaters serving the hot water demand of these products. Those internal loads interact with space conditioning requirements.

B.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 (4). The observed average efficiency 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 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.

Dishwashers. Historical average new unit efficiencies for dishwashers are available from AHAM for 1972, 1979, 1981, and 1983-87. NAECA requires that:

"dishwashers manufactured on or after January 1, 1988, shall be equipped with an option to dry without heat."

The implicit market discount rate for this product is calculated from the 1987 data, after correcting the usage frequency to agree with field surveys rather than the DOE test procedure. Further reductions in unit energy consumption are projected if a design with lower unit energy consumption has a lower life cycle cost, calculated using the market discount rate.

Clothes washers. Historical time-series data on average unit efficiencies of clothes washers are available for 1972, 1979, 1981, and 1983-87. NAECA requires that:

"All rinse cycles of clothes washers shall include an unheated water option, but may have a heated water rinse option, for products manufactured on or after January 1, 1988."

Engineering estimates are made of the designs (and their prices) potentially available during the forecast period (1987-2015). The average efficiency of unit purchased in 1987 is used to determine the implicit market discount rate for this product. The implicit market discount rate for this product is calculated from 1987 data, after correcting the usage frequency to agree with field surveys rather than the DOE test procedure. Average unit efficiency is projected to change as a function of projected residential energy prices.

Clothes dryers. The average unit energy consumption of new electric and gas clothes dryers is available from the AHAM for 1972 and 1980. No more recent data has been collected, because this product is not part of the FTC appliance labeling program. NAECA requires that:

"Gas clothes dryers shall not be equipped with a constant burning pilot for products manufacturer on or after January 1, 1988."

The implicit market discount rate for this product is calculated from the 1980 data, after correcting the usage frequency to agree with field surveys rather than the DOE test procedure.

B.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 purchase the product. The market share elasticities include cross-price variables, where appropriate, to capture inter-fuel. An example of inter-fuel competition is the choice between clothes dryers fueled by electricity or by natural gas.

Dishwashers. These products have no significant competition from technologies using fuels other than electricity. The principal market share decisions are: purchase this product or not; and select among the available classes.† The fraction of potential purchasers who actually purchase the product is determined each year by applying the market share elasticities to the percent change in equipment price, operating expense, (which includes changes in electricity price and in unit energy consumption) and income. The market share elasticities are constant over the projection period. The market share obtained by each class in any future year is assumed to be a constant fraction of total product sales. Table B.2 shows the fractions of total product sales by class.

Table B.2. Percent of Product Sales for Each Class,
1987-2015

Product	Class	Percent of Annual Product Sales
Dishwashers	Standard (115V)	36
	Standard, Water Heating (115V)	62
	Compact (115V)	2

Clothes washers The fraction of potential purchasers who actually purchase the product is determined each year by applying the market share elasticities to the percent change in equipment price, operating expense, (which includes changes in electricity price and in unit energy consumption) and income. The market share elasticities are constant over the projection period. The market share obtained by each class in any future year is assumed to be a constant fraction of total product sales. Table B.3 shows the fractions of total product sales by class.

* The projection of new housing units completed is described above in B.2 Housing. The projection of potential replacements/retrofits is described below in B.7 Equipment Turnover.

† The classes of dishwashers are described in Chapter 3.

Table B.3. Percent of Product Sales for Each Class,
1987-2015

Product	Class	Percent of Annual Product Sales
Clothes Washers	Standard	96
	Compact	4

Clothes dryers. The fraction of potential purchasers who actually purchase each class is determined each year by applying the market share elasticities to the percent change in equipment price, operating expense, (which includes changes in electricity price and in unit energy consumption) and income. The market share elasticities are constant over the projection period. The market share obtained by each class in any future year is assumed to be a constant fraction of total product sales. Table B.4 shows the fractions of total product sales by class.

Table B.4. Percent of Product Sales for Each Class,
1987-2015

Product	Class	Percent of Annual Product Sales
Electric Clothes Dryers	Standard	94
	Compact (120V)	3
	Compact (240V)	3
Gas Clothes Dryers	Standard	100

B.6 USAGE BEHAVIOR

The usage elasticities for dishwashers, clothes washers, and clothes dryers are assumed to be zero. Historical usage (cycles per year) is taken from surveys of field usage for each product. Projected usage is assumed constant at the 1988 values. Table B.5 shows the reported frequencies of use. (5)

Table B.5. Frequency of Use of Appliances
(Cycles per Year)

Year	Clothes Washers	Clothes Dryers	Dishwashers
1971	406	na	416
1973	411	390	380
1974	411	390	369
1977	437	385	322
1978	na	na	307
1980	411	364	307
1981	411	359	291
1983	411	364	291
1984	416	385	291
1985	416	369	na
1986	406	359	260
1988	380	359	229

Source: The Procter & Gamble Co. (5)

B.7 EQUIPMENT TURNOVER

Average equipment lifetimes for dishwashers, clothes washers, and clothes dryers are taken from data provided by the AHAM (6). The data were averaged over respondents, giving percent of units retired as a function of years since purchase. These lifetimes are assumed to be constant over the projection period. The percent of products which survives, as a function of years after purchase, is taken from the same report. These retirement functions are shown in Table B.6.

Table B.6. Percent of Appliances Retiring

Year After Purchase	Dishwasher	Clothes washer	Clothes dryer
1-5	5	5.5	3
6-10	28	20.5	13.5
11-15	41	32	24
16-20	22	30.5	31.5
21-25	4	11.5	14
26-30	0	0	14
Average life (years):	12.6	14.1	17.1

B.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;
- total fuel expenditures.

The LBL-REM produces cumulative values for a period (1993-2015):

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

The LBL-REM produces cumulative values for new units purchased in a period (1993-2015):

- 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;
- total discounted life-cycle expenditures per unit by end-use and fuel type.

Product types usually correspond to end-uses.

B.9 CHANGES SINCE PREVIOUS TSD (7)

1. The set of classes has changed with the addition of compacts for all products and elimination of a separate class for large clothes washers (Chapter 3).
2. The set of design options, efficiencies and cost data have changed (Chapter 3).
3. Usage behavior has been changed to reflect more recent field survey (Section B.6).
4. Energy price projections have been updated (Chapter 4).

B.10 INPUT DATA

The complete input listing is available on electronic medium, readable by IBM-compatible personal computers. The input database includes demographic, economic, and engineering data. The input listing for products in the current proposed rule is reproduced here.

The following is the regular LBL-REM input for dishwashers, clothes washers, and clothes dryers.

For standards cases, simply replace the input values for two variables in each class of each product regulated. The two variables are labelled: "first year for standard" and "UEC of standard" (on pages B-11 to B-13 for dishwashers). For example, for dishwasher standards taking effect in 1993, change "first year for standard = 2016" to "first year for standard = 1993" on each of those pages. The appropriate UEC values are found in Table 5.1 for dishwashers, Table 5.8 for clothes washers, and Table 5.15 for clothes dryers (Chapter 5). For standard dishwashers, standard level 3 requires changing the second variable to "UEC of standard = 513.8" (see page B-11, following).

Dishwasher

total saturation = 1.00
electricity price multiplier = 1.10
ncalc = 2
ndr1 (1, read drate & curve) = 0
nv1 (# of eun inputs) = 1
nv5 (# of cap inputs) = 0
nv2 (# of peq inputs) = 0
nv4 (# of usage inputs) = 1
ndis (year to forecast eff) = 9

----- UEC of Stock Unit in Base Year by fuel type i (MMBtu/yr) -----

1	2	3	4	5	
0.00	0.00	0.00	0.00	2.2184	** SF **
0.00	0.00	0.00	0.00	2.2184	** MF **
0.00	0.00	0.00	0.00	2.2184	** MB **

----- Purchase Price of a Reference Unit (\$1987) -----

1	2	3	4	5	
0.00	0.00	0.00	0.00	311.69	** SF **
0.00	0.00	0.00	0.00	311.69	** MF **
0.00	0.00	0.00	0.00	311.69	** MB **

----- Relative UEC and Capacity of a Reference Unit to a Stock Unit -----

1	2	3	4	5	
1.00	1.00	1.00	1.00	1.0594	** re **
1.00	1.00	1.00	1.00	1.00	** recap**

----- Base Year Saturations - c70 (Source: AHAM) -----

1	2	3	4	5	6	
0.000	0.000	0.000	0.000	0.496	0.504	** SF **
0.000	0.000	0.000	0.000	0.293	0.707	** MF **
0.000	0.000	0.000	0.000	0.361	0.639	** MB **

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

1	2	3	4	5	6	
0.000	0.000	0.000	0.000	0.496	0.504	** SF **
0.000	0.000	0.000	0.000	0.293	0.707	** MF **
0.000	0.000	0.000	0.000	0.361	0.639	** MB **

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

1	2	3	4	5	6	
0.000	0.000	0.000	0.000	0.820	0.180	** SF **
0.000	0.000	0.000	0.000	0.805	0.195	** MF **
0.000	0.000	0.000	0.000	0.440	0.560	** MB **

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

5 Dishwashers

2.738	3.488	3.557	3.356	3.140	2.702	3.320	3.702	3.199	2.477
2.116	2.118	1.960	1.586	1.528	1.262	1.050	0.880	0.720	0.620
0.555	0.547	0.425	0.390	0.000	0.000	0.000	0.000	0.000	0.000

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

all i

0.010	0.010	0.010	0.010	0.010	0.056	0.056	0.056	0.056	0.056
0.082	0.082	0.082	0.082	0.082	0.044	0.044	0.044	0.044	0.044
0.008	0.008	0.008	0.008	0.008	0.000	0.000	0.000	0.000	0.000

----- Average Life Times (by Fuel Type i) -----

1	2	3	4	5
0.0	0.0	0.0	0.0	12.6

----- Operating Cost Elasticities (for 5 Fuel Types and Income) -----

1	2	3	4	5	6	
0.00	0.00	0.00	0.00	0.00	0.00	/* j=1 */
0.00	0.00	0.00	0.00	0.00	0.00	/* j=2 */
0.00	0.00	0.00	0.00	0.00	0.00	/* j=3 */
0.00	0.00	0.00	0.00	0.00	0.00	/* j=4 */
0.00	0.00	0.00	0.00	-0.075	0.00	/* j=5 */
0.00	0.00	0.00	0.00	0.50	-0.50	/* j=6 */

----- Equipment Price Elasticities (for 5 Fuel Types) -----

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

----- Usage Elasticities (for 5 Fuel Types and Income) -----

1	2	3	4	5	
0.00	0.00	0.00	0.00	0.00	/* j=1 */
0.00	0.00	0.00	0.00	0.00	/* j=2 */
0.00	0.00	0.00	0.00	0.00	/* j=3 */
0.00	0.00	0.00	0.00	0.00	/* j=4 */
0.00	0.00	0.00	0.00	-0.10	/* j=5 */
0.00	0.00	0.00	0.00	0.10	/* j=6 */

----- Historical Relative Energy Use (EUN) for New Units -----

i	1	1981	1982	1983	1984	1985	1986	1987	1988
5	0	1.002	0.975	0.948	0.948	0.948	0.923	0.923	0.932

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

i	1	1980	1981	1982	1983	1984	1985	1986	1987	1988
0	0	1.073	1.017	1.017	1.017	1.017	1.017	0.909	0.955	1.000

of products in dishwasher = 1

=====

product type id# = 6
product name = DWas (Dishwasher)
end-use id# = 13
fuel type id# = 5
reference unit UEC (kWh) = 661.9
reference unit price (\$1987) = 311.69
number of classes = 3

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

class id# = 17
class name = Std (Standard Dishwashers)
discount rate = 0.99
first year to forecast UEC = 1988
first year for standard = 2016
UEC of standard = 513.8
conversion (kWh-MMBtu&usage) = .011500

----- Historical Energy Factors

1981	1982	1983	1984	1985	1986	1987	1988
0.332	0.341	0.351	0.351	0.351	0.360	0.360	0.350

----- Adjusted Volumes (1981-2015) 1.0 * 229/365 (229 cycles/yr)

0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274
0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274
0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274
0.6274	0.6274	0.6274	0.6274	0.6274					

----- Fraction of Market Share (1981-2015)

.363	.363	.363	.363	.363	.363	.363	.363	.363	.363
.363	.363	.363	.363	.363	.363	.363	.363	.363	.363
.363	.363	.363	.363	.363	.363	.363	.363	.363	.363
.363	.363	.363	.363	.363					

----- UEC (kWh) & Purchase Price (\$1987) Data

kWh	Price	hot wat	tot wat (229 cyl/yr)
715.6	300.03	2729.7	2729.7
597.7	310.81	2184.7	2184.7
585.0	317.14	2184.7	2184.7
522.1	332.36	1696.8	2184.7
513.8	325.98	1696.8	2184.7
509.8	345.03	1646.0	2118.3
501.1	332.27	1696.8	2184.7
489.5	344.96	1646.0	2118.3

----- Shipment Distribution (Source: FTC)

kWh	Units
480.9	1.0
572.5	12.0
641.2	7.0
664.1	16.0
687.0	3.0
709.9	13.0
732.8	11.0

----- the 2nd class -----

class id# = 18

class name = WHDW (Standard Water Heating Dishwashers)

discount rate = 0.86

first year to forecast UEC = 1988

first year for standard = 2016

UEC of standard = 513.2

conversion (kWh-MMBtu&usage) = .011500

----- Historical Energy Factors

1981	1982	1983	1984	1985	1986	1987	1988
0.350	0.360	0.370	0.370	0.370	0.380	0.380	0.380

----- Adjusted Volumes (1981-2015) 1.0 * 229/365 (229 cycles/yr)

0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274
0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274
0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274
0.6274	0.6274	0.6274	0.6274	0.6274					

----- Fraction of Market Share (1981-2015)

.619	.619	.619	.619	.619	.619	.619	.619	.619	.619
.619	.619	.619	.619	.619	.619	.619	.619	.619	.619
.619	.619	.619	.619	.619	.619	.619	.619	.619	.619
.619	.619	.619	.619	.619					

----- UEC (kWh) & Purchase Price (\$1987) Data

kWh Price hot wat tot wat (229 cyl/yr)

636.1	320.03	2117.3	2725.1
534.1	330.81	1693.7	2180.1
513.2	333.71	1693.7	2180.1
500.5	339.90	1693.7	2180.1
488.9	352.43	1642.8	2113.7

----- Shipment Distribution (Source: FTC)

kWh Units

343.5	1.0
503.8	13.0
526.7	19.0
549.6	36.0
572.5	18.0
595.4	30.0
618.3	21.0
641.2	19.0
664.1	45.0
687.0	2.0
709.9	1.0

----- the 3rd class -----

class id# = 19
class name = COMP (Compact Dishwashers 115V)
discount rate = 0.59
first year to forecast UEC = 1988
first year for standard = 2016
UEC of standard = 382.5
conversion (kWh-MMBtu&usage) = .011500

----- Historical energy factors

1981	1982	1983	1984	1985	1986	1987	1988
0.451	0.464	0.477	0.477	0.477	0.490	0.490	0.490

----- Adjusted volumes (1981-2015) 1.0 * 229/365 (229 cycles/yr)

0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274
0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274
0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274	0.6274
0.6274	0.6274	0.6274	0.6274	0.6274					

----- Fraction of market share (1981-2015)

.018	.018	.018	.018	.018	.018	.018	.018	.018	.018
.018	.018	.018	.018	.018	.018	.018	.018	.018	.018
.018	.018	.018	.018	.018	.018	.018	.018	.018	.018
.018	.018	.018	.018	.018					

----- UEC (kWh) & Purchase Price (\$1987) Data

kWh Price hot wat tot wat (229 cyl/yr)

467.3	260.03	1465.9	1887.0
397.0	270.80	1172.5	1509.1
382.5	273.71	1172.5	1509.1
371.1	279.89	1172.5	1509.1
363.0	292.43	1137.6	1463.3

----- Shipment Distribution (Source: FTC)

kWh Units

467.3	1.0
-------	-----

Washer

total saturation = 1.00

electricity price multiplier = 1.10

ncalc = 2

ndr1 (1, read drate & curve) = 0

nv1 (# of eun inputs) = 1

nv5 (# of cap inputs) = 0

nv2 (# of peq inputs) = 0

nv2 (# of usage inputs) = 1

ndis (year to forecast eff) = 9

----- UEC of Stock Unit in Base Year by Fuel Type i (MMBtu/yr) -----

1	2	3	4	5	
0.00	0.00	0.00	0.00	1.1722	** SF **
0.00	0.00	0.00	0.00	1.1722	** MF **
0.00	0.00	0.00	0.00	1.1722	** MB **

----- Purchase Price of a Reference Unit (\$1987) -----

1	2	3	4	5	
0.00	0.00	0.00	0.00	396.44	** SF **
0.00	0.00	0.00	0.00	396.44	** MF **
0.00	0.00	0.00	0.00	396.44	** MB **

----- Relative UEC and Capacity of a Reference Unit to a Stock Unit -----

1	2	3	4	5	
1.00	1.00	1.00	1.00	1.13	** re **
1.00	1.00	1.00	1.00	1.00	** recap**

----- Base Year Saturations - c70 (Source: AHAM) -----

1	2	3	4	5	6	
0.000	0.000	0.000	0.000	0.785	0.215	** SF **
0.000	0.000	0.000	0.000	0.556	0.444	** MF **
0.000	0.000	0.000	0.000	0.609	0.391	** MB **

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

1	2	3	4	5	6	
0.000	0.000	0.000	0.000	1.000	0.000	** SF **
0.000	0.000	0.000	0.000	0.750	0.250	** MF **
0.000	0.000	0.000	0.000	0.800	0.200	** MB **

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

1	2	3	4	5	6	
0.000	0.000	0.000	0.000	0.939	0.061	** SF **
0.000	0.000	0.000	0.000	0.664	0.336	** MF **
0.000	0.000	0.000	0.000	0.729	0.271	** MB **

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

5 Clothes Washers

4.816	5.264	5.348	4.933	4.493	4.228	4.948	5.504	5.163	4.495
3.869	4.068	4.103	3.880	3.892	3.771	3.541	3.300	2.975	2.666
2.561	2.932	2.780	2.783	0.000	0.000	0.000	0.000	0.000	0.000

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

all i

0.011	0.011	0.011	0.011	0.011	0.041	0.041	0.041	0.041	0.041
0.064	0.064	0.064	0.064	0.064	0.061	0.061	0.061	0.061	0.061
0.023	0.023	0.023	0.023	0.023	0.000	0.000	0.000	0.000	0.000

----- Average Life Times (by Fuel Type i) -----

1	2	3	4	5
0.0	0.0	0.0	0.0	14.1

----- Operating Cost Elasticities (for 5 Fuel Types and Income) -----

1	2	3	4	5	6	
0.00	0.00	0.00	0.00	0.00	0.00	/* j=1 */
0.00	0.00	0.00	0.00	0.00	0.00	/* j=2 */
0.00	0.00	0.00	0.00	0.00	0.00	/* j=3 */
0.00	0.00	0.00	0.00	0.00	0.00	/* j=4 */
0.00	0.00	0.00	0.00	-0.210	0.00	/* j=5 */
0.00	0.00	0.00	0.00	0.50	-0.50	/* j=6 */

----- Equipment Price Elasticities (for 5 Fuel Types) -----

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

----- Usage Elasticities (for 5 Fuel Types and Income) -----

1	2	3	4	5	
0.00	0.00	0.00	0.00	0.00	/* j=1 */
0.00	0.00	0.00	0.00	0.00	/* j=2 */
0.00	0.00	0.00	0.00	0.00	/* j=3 */
0.00	0.00	0.00	0.00	0.00	/* j=4 */
0.00	0.00	0.00	0.00	-0.10	/* j=5 */
0.00	0.00	0.00	0.00	0.10	/* j=6 */

----- Historical Relative Energy Use (EUN) for New Units -----

i	1	1981	1982	1983	1984	1985	1986	1987	1988
5	0	0.781	0.781	0.781	0.781	0.781	0.781	0.781	0.781

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

i	1	1980	1981	1982	1983	1984	1985	1986	1987	1988
5	0	1.082	1.082	1.082	1.082	1.095	1.095	1.068	1.034	1.000

of products in Washer = 1

product type id# = 7
product name = CWas (Standard Clothes Washer)
end-use id# = 14
fuel type id# = 5
reference unit UEC (kWh) = 936.0
reference unit price (\$1987) = 396.44
number of classes = 2

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

class id# = 31
class name = Std (Standard Clothes Washers)
discount rate = 2.16
first year to forecast UEC = 1988
first year for standard = 2016
UEC of standard = 949.8
conversion (kWh-MMBtu&usage) = .011500

———— Historical Energy Factors

1981	1982	1983	1984	1985	1986	1987	1988
1.351	1.351	1.351	1.351	1.351	1.351	1.351	1.351

———— Adjusted Volumes (1981-2015) 2.6(actual vol) * 380/365 (380 cycles/yr)

2.707	2.707	2.707	2.707	2.707	2.707	2.707	2.707	2.707	2.707
2.707	2.707	2.707	2.707	2.707	2.707	2.707	2.707	2.707	2.707
2.707	2.707	2.707	2.707	2.707	2.707	2.707	2.707	2.707	2.707
2.707	2.707	2.707	2.707	2.707					

———— Fraction of Market Share (1981-2015)

0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
0.96	0.96	0.96	0.96	0.96					

———— UEC (kWh) & Purchase Price (\$1987) Data

kWh Price hot wat tot wat (380 cyl/yr)

949.8	400.04	3925.4	12650.2
746.5	400.04	2983.0	12650.2
673.7	400.04	2644.8	12650.2
660.1	411.53	2644.8	12650.2
656.8	421.07	2633.4	12650.2
653.1	441.79	2614.4	12650.2
261.8	570.86	946.2	8667.8
260.5	580.41	942.4	8667.8
259.3	601.14	934.8	8667.8

———— Shipment Distribution (Source: FTC# of Models, 380cyl/yr)

kWh	Units
722.	9.
798.	53.
874.	57.
950.	41.
1026.	31.
1102.	34.
1178.	67.
1254.	17.
1330.	2.
1406.	28.
1482.	2.
1558.	2.
1672.	1.

----- the 2nd class -----
class id# = 32
class name = COMP (Compact Clothes Washer)
discount rate = 1.40
first year to forecast UEC = 1988
first year for standard = 2016
UEC of standard = 473.7
conversion (kWh-MMBtu&usage) = .011500

----- Historical Energy Factors

1981	1982	1983	1984	1985	1986	1987	1988
1.163	1.163	1.163	1.163	1.163	1.163	1.163	1.163

----- Adjusted Volumes (1981-2015) 1.45(actual vol) * 380/365 (380 cycles/yr)

1.510	1.510	1.510	1.510	1.510	1.510	1.510	1.510	1.510	1.510
1.510	1.510	1.510	1.510	1.510	1.510	1.510	1.510	1.510	1.510
1.510	1.510	1.510	1.510	1.510	1.510	1.510	1.510	1.510	1.510
1.510	1.510	1.510	1.510	1.510					

----- Fraction of Market Share (1981-2015)

0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
0.04	0.04	0.04	0.04	0.04					

----- UEC (kWh) & Purchase Price (\$1987) Data

kWh	Price hot	wat tot	wat (416 cyl/yr)
605.2	310.03	2363.6	7729.2
482.8	310.03	1793.6	7729.2
439.0	310.03	1592.2	7729.2
426.3	321.53	1592.2	7729.2
424.2	331.06	1584.6	7729.2
422.2	351.78	1573.2	7729.2
146.0	480.85	528.2	4833.6
145.3	490.40	524.4	4833.6
144.6	511.13	520.6	4833.6

----- Shipment Distribution (Source: FTC# of Models, 380cyl/yr)

kWh	Units
570.	18.
646.	10.
798.	3.
950	4.
1026.	8.
1330.	1.

Dryer
 total saturation = 1.00
 electricity price multiplier = 1.10
 ncalc = 2
 ndr1 (1, read drate & curve) = 0
 nv1 (# of eun inputs) = 2
 nv5 (# of cap inputs) = 0
 nv2 (# of peq inputs) = 0
 nv4 (# of usage inputs) = 1
 ndis (year to forecast eff) = 9

----- UEC of Stock Unit in Base Year by Fuel Type i (MMBtu/yr) -----

1	2	3	4	5	
10.652	4.071	0.00	0.00	0.00	** SF **
10.652	4.071	0.00	0.00	0.00	** MF **
10.652	4.071	0.00	0.00	0.00	** MB **

----- Purchase Price of a Reference Unit (\$1987) -----

1	2	3	4	5	
297.93	340.03	0.00	0.00	0.00	** SF **
297.93	340.03	0.00	0.00	0.00	** MF **
297.93	340.03	0.00	0.00	0.00	** MB **

----- Relative UEC and Capacity of a Reference Unit to a Stock Unit -----

1	2	3	4	5	
1.0078	0.9157	1.00	1.00	1.00	** re **
1.00	1.00	1.00	1.00	1.00	** recap**

----- Base Year Saturations - c70 (Source: AHAM)-----

1	2	3	4	5	6	
0.531	0.149	0.000	0.000	0.000	0.320	** SF **
0.368	0.103	0.000	0.000	0.000	0.529	** MF **
0.400	0.112	0.000	0.000	0.000	0.488	** MB **

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

1	2	3	4	5	6	
0.577	0.162	0.000	0.000	0.000	0.261	** SF **
0.400	0.112	0.000	0.000	0.000	0.488	** MF **
0.434	0.122	0.000	0.000	0.000	0.444	** MB **

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

1	2	3	4	5	6	
0.722	0.202	0.000	0.000	0.000	0.076	** SF **
0.501	0.140	0.000	0.000	0.000	0.359	** MF **
0.544	0.152	0.000	0.000	0.000	0.304	** MB **

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

1 Electric Dryers

2.494	2.783	2.865	2.817	2.466	2.198	2.845	3.330	2.989	2.527
2.129	2.117	1.986	1.819	1.609	1.388	1.194	1.059	0.923	0.773
0.806	0.906	0.824	0.880	0.000	0.000	0.000	0.000	0.000	0.000

2 Gas Dryers

0.682	0.768	0.757	0.736	0.708	0.672	0.739	0.926	0.936	0.850
0.851	0.905	0.876	0.828	0.751	0.710	0.632	0.534	0.475	0.410
0.429	0.477	0.378	0.392	0.000	0.000	0.000	0.000	0.000	0.000

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

all i

0.006	0.006	0.006	0.006	0.006	0.027	0.027	0.027	0.027	0.027
0.048	0.048	0.048	0.048	0.048	0.063	0.063	0.063	0.063	0.063
0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028

----- Average Life Times (by Fuel Type i) -----

1	2	3	4	5
17.1	17.1	0.0	0.0	0.0

----- Operating Cost Elasticities (for 5 Fuel Types and Income) -----

1	2	3	4	5	6	
-.109	0.00	0.00	0.00	0.00	0.00	/* j=1 */
0.00	-.087	0.00	0.00	0.00	0.00	/* j=2 */
0.00	0.00	0.00	0.00	0.00	0.00	/* j=3 */
0.00	0.00	0.00	0.00	0.00	0.00	/* j=4 */
0.00	0.00	0.00	0.00	0.00	0.00	/* j=5 */
0.50	0.20	0.00	0.00	0.00	-0.50	/* j=6 */

----- Equipment Price Elasticities (for 5 Fuel Types) -----

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

----- Usage Elasticities (for 5 Fuel Types and Income) -----

1	2	3	4	5	
-0.10	0.00	0.00	0.00	0.00	/* j=1 */
0.00	-0.10	0.00	0.00	0.00	/* j=2 */
0.00	0.00	0.00	0.00	0.00	/* j=3 */
0.00	0.00	0.00	0.00	0.00	/* j=4 */
0.00	0.00	0.00	0.00	0.00	/* j=5 */
0.10	0.10	0.00	0.00	0.00	/* j=6 */

----- Historical Relative Energy Use (EUN) for New Units -----

i	1	1981	1982	1983	1984	1985	1986	1987	1988
1	0	1.026	1.022	1.019	1.014	1.011	1.007	1.004	1.000
2	0	1.012	1.010	1.008	1.006	1.004	1.002	1.000	1.000

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

i	1	1980	1981	1982	1983	1984	1985	1986	1987	1988
0	0	1.014	1.000	1.014	1.014	1.072	1.028	1.000	1.000	1.000

of products in dryers = 2

=====

product type id# = 4
 product name = EDry (Electric Dryer)
 end-use id# = 10
 fuel type id# = 1
 reference unit UEC (kWh) = 933.4
 reference unit price (\$1987) = 297.93
 number of classes = 3

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

class id# = 13
 class name = Std (Standard Electric Dryer)
 discount rate = 0.80
 first year to forecast UEC = 1988
 first year for standard = 2016
 UEC of standard = 966.5
 conversion (kWh-MMBtu&usage) = .011500

----- Historical Energy Factors

1981	1982	1983	1984	1985	1986	1987	1988
2.69	2.70	2.71	2.72	2.73	2.74	2.75	2.76

----- Adjusted volumes (1981-2015) (7*359/365) where 359=cycles/year

6.8849	6.8849	6.8849	6.8849	6.8849	6.8849	6.8849	6.8849	6.8849	6.8849
6.8849	6.8849	6.8849	6.8849	6.8849	6.8849	6.8849	6.8849	6.8849	6.8849
6.8849	6.8849	6.8849	6.8849	6.8849	6.8849	6.8849	6.8849	6.8849	6.8849
6.8849	6.8849	6.8849	6.8849	6.8849					

----- Fraction of Market Share (1981-2015)

0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
0.94	0.94	0.94	0.94	0.94					

----- UEC (kWh) & Purchase Price (\$1987) Data

kWh	Price
966.5	300.03
850.6	313.01
833.5	323.72
783.5	372.34
616.8	467.45
291.7	695.31

----- Shipment Distribution (Source: none)

kWh	Units
966.5	1.

----- the 2nd class -----

class id# = 14
class name = 120V (Compact Electric Dryer 120V)
discount rate = 0.33
first year to forecast UEC = 1988
first year for standard = 2016
UEC of standard = 398.9
conversion (kWh-MMBtu&usage) = .011500

----- Historical energy factors

1981	1982	1983	1984	1985	1986	1987	1988
2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82

----- Adjusted volumes (1981-2015) (3*359/365) where 359=cycles/year

2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507
2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507
2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507
2.9507	2.9507	2.9507	2.9507	2.9507					

----- Fraction of Market Share (1981-2015)

0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
0.03	0.03	0.03	0.03	0.03					

----- UEC (kWh) & Purchase Price (\$1987) Data

kWh	Price
398.9	250.03
351.0	263.01
344.0	273.71
323.4	322.33
254.6	417.44
120.4	645.31

----- Shipment Distribution (Source: none)

kWh	Units
398.9	1.

----- the 3rd class -----

class id# = 15
class name = 240V (Compact Electric Dryer 240V)
discount rate = 0.36
first year to forecast UEC = 1988
first year for standard = 2016
UEC of standard = 430.8
conversion (kWh-MMBtu&usage) = .011500

----- Historical Energy factors

1981	1982	1983	1984	1985	1986	1987	1988
2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63

----- Adjusted Volumes (1981-2015) (3*359/365) where 359=cycles/year

2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507
2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507
2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507	2.9507
2.9507	2.9507	2.9507	2.9507	2.9507					

----- Fraction of Market Share (1981-2015)

0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
0.03	0.03	0.03	0.03	0.03					

----- UEC (kWh) & Purchase Price (\$1987) Data

kWh	Price
430.8	280.03
379.1	293.01
371.5	303.71
349.2	352.34
274.9	447.44
130.0	675.31

----- Shipment Distribution (Source: none)

kWh Units
430.8 1.

product type id# = 5
product name = GDry (Gas Dryer)
end-use id# = 10
fuel type id# = 2
reference unit UEC (MMBtu) = 3.728
reference unit price (\$1987) = 340.03
number of classes = 1

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

class id# = 16
class name = Gas Dryer, Standard
discount rate = 0.26
first year to forecast UEC = 1988
first year for standard = 2016
UEC of standard = 3.728
conversion (usage) = 1.000

----- Historical Energy Factors

1981	1982	1983	1984	1985	1986	1987	1988
2.43	2.43	2.44	2.44	2.45	2.45	2.46	2.46

----- Adjusted Volumes (1981-2015) (7*359/365 * .003412)

.023491 .023491 .023491 .023491 .023491 .023491 .023491 .023491 .023491 .023491
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.023491 .023491 .023491 .023491 .023491

----- Fraction of Market Share (1981-2015)

1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00					

----- UEC (MMBtu) & Purchase Price (\$1987) Data

MMBtu	Price
3.728	340.03
3.281	353.02
3.215	363.72
3.022	412.34

----- Shipment Distribution (Source: none)

kWh Units
3.728 1.

B.11 REFERENCES

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APPENDIX C. LBL MANUFACTURER IMPACT MODEL

C.1 OVERVIEW OF MANUFACTURER IMPACT MODEL

C.1.1 Purpose

The LBL-MIM collects all the calculations to determine the impact of a change in appliance efficiency standards on an industry's profitability and scale of operation into one spreadsheet. Collecting the calculations into a single spreadsheet makes it possible to analyze quickly the effects of uncertainties in input values, and to update the calculations efficiently as new data arrive. 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

Appliance manufacturers may be affected by a change in efficiency standards, depending on the interaction of three factors: 1) the costs imposed by the change in standards; 2) the price elasticity of a single firm; and 3) the industry's elasticities of demand. The LBL-MIM integrates and analyzes these three 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 the changes in the primary outputs.

C.1.4 Methodology

How standards are implemented in the model

A change in standards affects the model in three distinct ways. In general, stricter standards require additional investment, raise production costs, and affect revenue.

The most obvious investment induced by standards is the purchase of new plant 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 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 by both 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. Demand is determined by price and operating cost elasticities, coupled with the changes in price and operating costs resulting from the standards.

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. A four-year period is 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 manufacturing firms are proprietary, LBL-MIM models a prototypical firm. In many cases this must be thought of as representing a 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 refrigerator/freezers with automatic defrost or extra-quiet dishwashers. Products without such desirable features are generally bought in larger quantities at lower prices by consumers who are more highly 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. For dishwashers, clothes washers, and clothes dryers, the markup may vary depending on the features of a unit, but average markups of products do not vary among product classes or product types.

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, an intuitive understanding of the relevant economics will be useful.

Economists 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.*

The first point may be understood by assuming for a moment that it is false and that price is higher than marginal cost. In this case, each firm would think it profitable to produce more because in perfect competition each knows that as an individual firm it can have no effect on price. This would certainly drive price 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.

* Two 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, 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.

Profit Maximization and Fixed Costs

Figure C.1. Increase in Fixed Costs

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 made with an eye to the time horizon under consideration because 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 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 the ones that it foresaw at the time it planned its present capacity), then long- and short-run marginal costs 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. 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 be 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

Because the presence of fixed costs in the production of the appliances analyzed, unit cost decreases as quantity increases. This cost structure is not compatible with a perfectly competitive industry. Producers with large-scale production can achieve lower unit costs than small producers. Consequently, each producing firm must not face an infinite elasticity of demand. A small increase in price charged will not result in a 100% loss of sales due to induced entry of competitors. Thus, the LBL-MIM models typical firms as having economies of scale in production 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 and these derivations are included for the convenience of the reader and not as an explanation of theoretical results new to this study.

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):

$$C = b_1 0 + b_1 1 Q . \quad (C.1)$$

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

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 a ROE equal to the cost of capital will find its economic profit is 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:

$$\frac{d}{dQ} [R - b_1 0 - b_1 1 Q] = 0$$

$$\rightarrow R' = b_1 1 .$$

* If we assume that cost is an arbitrary function of Q , $C(Q)$, our final result, will differ only in that the two types of cost (w_0 and w_1) will be replaced by $C - Q \frac{dC}{dQ}$ and $\frac{dC}{dQ}$, respectively.

By definition:

$$\begin{aligned}
 R &= P \cdot Q \\
 \rightarrow R' &= P' \cdot Q + P \\
 \rightarrow R' &= \frac{P}{\frac{dQ}{dP} \frac{P}{Q}} + P \\
 \rightarrow R' &= \frac{P}{e} + P \\
 \rightarrow P &= \frac{e}{1+e} b_1 \cdot 1.
 \end{aligned} \tag{C.4}$$

Equation C.4 price as a simple markup over marginal cost; this equation can be found in any standard text on industrial organization. Now define the markup:

$$\mu = \frac{e}{1+e}. \tag{C.5}$$

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 Equation C.4 provides a simpler look at the markup equation:

$$P = \mu b_1 \cdot 1. \tag{C.6}$$

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

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

$$(R - C) = R - b_1 \cdot 0 - b_1 \cdot 1 \cdot Q.$$

Using Equation (C.5)

$$R = P \cdot Q = \mu b_1 \cdot 1 Q,$$

so

$$(R - C) = \mu b_1 \cdot 1 Q - b_1 \cdot 0 - b_1 \cdot 1 Q,$$

and

$$(R - C) = (\mu - 1) b_1 \cdot 1 Q - b_1 \cdot 0.$$

Finally,

$$\mu = 1 + \frac{(R - C) + b_1 \cdot 0}{b_1 \cdot 1 Q}. \tag{C.7}$$

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 use a simple variation of this equation in which $b_1 \cdot 1 Q$ is replaced by $C - b_1 \cdot 0$, and the relation $R - C = EP$, where EP is economic profit is used twice. The new form of the equation is:

$$\mu = 1 + \frac{EP + b_1 \cdot 0}{R - EP - b_1 \cdot 0}. \tag{C.8}$$

Markup is determined by three variables: 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 Section 7.1, Industry Profile, we see that the market structure of the home appliance industry is an oligopoly and model it accordingly. However, the situation is 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.* In other words, we have an oligopoly facing an oligopsony. Consequently, the standard oligopoly model needs to be modified. Unfortunately, there is no received theory on the modeling 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 our 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 include 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%. 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 markup estimates 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 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 will call 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 oligopsonistic, 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 will provide 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.

* The increasing concentration in the demand-side of the market agrees with comments by the home appliance industry during the comment period for these and for 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 Dishwashers, Clothes Washers and Clothes Dryers," CE-RM-88-101, October 10, 1989.

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

$$e = NF * e_i, \quad (C.9)$$

where

- e = the firm's elasticity of demand,
- e_i = industry's elasticity of demand, and
- NF = number of firms.

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

$$e = \frac{\mu}{1-\mu}. \quad (C.10)$$

We can find the markup, μ in Equation (C.10) from Equation (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:

$$\mu = \frac{P}{c} = \frac{P}{P - \frac{FC}{Q} - \frac{\pi}{Q}} = \frac{R}{R - FC - \pi} \quad (C.11)$$

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

$$NF = \frac{\mu}{e_i * (1-\mu)} \quad (C.12)$$

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

* See section C.3.2 for more detail on data sources.

To summarize, we first look at a typical firm's profit and fixed costs. In order to cover fixed costs, a firm must mark up over variable cost, 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 market power or the elasticity of the demand curve it faces. This elasticity is related to the industry's demand elasticity and the "effective" number of firms in the industry, NF , as shown in Equation (C.9). Thus, we account for the oligopsony power of the large retailers and the oligopoly power of the manufacturers by estimating an NF that represents the effective competitiveness of the industry and using it in subsequent calculations.

The Base Case: 1990 NAECA standards

In the *long-run model module*, calibration is immediately followed by long-run calculations for the state of the industry in 1996 with the 1990 NAECA standards unmodified. These calculations use the markup that is based on the one just calculated in C.8, 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 equation 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:

$$Q = a * (P + ff * F)^B,$$

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

$$e = \frac{B * P}{P + ff * F}.$$

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 fall into two varieties: tooling and equipment. These are not currently separated by the model because separate data were not provided by 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 $b10$, and the remainder is divided by Q and added to $b11$.

Because 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 $b11$.

Once base case costs have been assigned, price is easily computed from Equation (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 $R=P \cdot Q$, and economic income is just $R-C$. Assets are those of the calibration case plus the new capital resulting from the 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, 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.

$$EC=FC+MCq \cdot Q .$$

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

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

Demand elasticity. With respect to life-cycle cost, the demand elasticity 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 a 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 alter this figure.

Amortization of capital costs. It is assumed that the one-time capital cost is to be amortized over its life (typically eight 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-123 spreadsheet that is organized into 12 modules or pages. A flow chart depicting the main connections among these appears in Figure (C.2), and a brief description of each is given below. Starting with subsection C2.3.1, each panel is given a full description.

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 "Weighting" 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.* In the Small Gas Furnace analysis, it is found that for each possible standards level a number of engineering designs will be produced. This module weights the costs given by the engineering model in proportion to the number of appliances 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 Levels 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 the 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: *shipment*, *price*, *revenue*, *net income*, and *ROE*. The first column gives the output values in the BASE case—that is, the case in which the 1993 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 1996). 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, e.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 industry's operating cost elasticity of demand (ICE);
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 (FIX);
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 simply 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 are changes in long- and short-run return on equity (ROE). Because these last two variables start out as percentages, the changes presented here are simple differences between their values before and after a change in standards.

C.2.3.3 The Account Module

The Accounting Summary consists of a simplified income statement that is presented in standard form, and several key financial ratios and figures that highlight the firm's financial position. The income statement and financial ratios are presented for the 1987 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.

MIM Modules and Primary Routes of Data Flow

Table C.1 lists the equations that are used in the Accounting module.

Table C.1. Accounting Module

Item	Formula
Earnings Before Int. 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 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.

It may help to note that “one-time” (1-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 1987 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 1987 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*: These engineering input data are the energy use per year measured in kilowatt hours, except in the case of gas dryers. For gas dryers the energy use is measured in million BTUs per year.
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 millions of 1987 dollars.
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 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:

$$EE_i = EE:CC * MxCC * CC_i,$$

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. Three of the engineering tables are omitted because they are used only to produce the other three. The omitted tables are "Increment in Additional UVC", "Capital / unit / 7", and "Additional Capital Cost".

The data that appear in the three tables—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 LBL-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 on a particular run. The module is used interactively by the user, who can choose "levels" LEV.B and LEV.L, which correspond to the Base case and Long-Run case. 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 S|E.B=0, then the columns of VCB, KWB, CCB, and EEB will contain data for the fourth engineering design option. Changing S|E.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 serves two functions. First, it provides the Model module with a few 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.

Table C.2. 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. (industry shipments <i>mb</i> firm market share)
Price (P.1)	Retail price / retail markup
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%)

The "Totals" row gives total industry shipments, total firm shipments (Q), weighted average price (P), total firm revenue (R), weighted average markup, and weighted average UVC.

Table C.2. Costs, Sales, and Revenue Module (cont.)

1996 Base Case and New Standards Case	
Item	Formula or Definition
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 Mark.B	$Wghtd\ dP = q\% * M.1mbChange\ in\ UVC$ $(P.B - P) / \sum Wghtd\ dP$
New Price (Pi.B)	$P.1 + Mark.B * M.1mbChange\ in\ UVC$
Operating Cost Ratio	1996 Unit Energy Consumption (UEC)/1987 UEC
Weighted Oper. Cost Ratio	Oper. Cost Ratio <i>mb</i> Relative Shipments (Q%)
New Shipments (Qi.B)	$Q\% * Q.B$
New Revenue (Ri.B)	$Pi.B * Qi.B$

In the new-standards case, the variables are named with a ".L" 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 1987 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*).

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 Inputs page. 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 level, revenue, and the weighted-average change in unit variable cost and price.

The manufacturer markup listed 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.* This markup is over *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 than 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 dishwasher manufacturing industry (called "DA:R") is 0.151. 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 lists the equations used in the Financial Inputs module.

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

Table C.3. Financial Module

Item	Formula
Depreciation (DR:R = Depreciable assets as a percentage of revenues)	Average depreciation rate x DR:R
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 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 Analysis 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 1987 calibration case to the 1996 base case that includes the 1990 standards, and for the change from the 1987 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%—100%) 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.* 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.

In two ways this procedure overestimates the burden to the firm. First, engineering cost 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 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. This table should be read in conjunction with the One-Time Cost Amortization module of MIM. 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.

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

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	$\ln(1+ATWACC)$
CC _i	Capital cost <i>i</i> years before standards	
EE _i	Engineering expense <i>i</i> years before standards	
WCC _i	(see 1-X Cost module)	$CC_i * \exp(ATR * i)$
WEE _i	(see 1-X Cost module)	$EE_i * \exp(ATR * i)$
LTC	(see 1-X Cost module)	Sum of WCC _i over 4 years
LTE	(see 1-X Cost module)	Sum of WEE _i 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 cap. 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 1-X Cost module)	$\frac{1 - ATR * L * EMRL / (1-EMRL)}{1-EMRL}$
AFC	(see 1-X Cost module)	$\frac{1 - ATR * TL * EMRT / (1-EMRT)}{1-EMRL}$
B:T	(see 1-X Cost module)	$(1-EMRT) / (ATR / BN + 1-EMRT)$
AFF	Average asset factor	$B:T * AFB + (1-B:T) * AFC$

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 which 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 AFC 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 1-X 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 Base case 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 .L refer to the 1990 NAECA standards and the 1993 NAECA standards, respectively. A combined suffix such as .BF has the natural interpretation interpretation, i.e., 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 variable costs are not given as dollars and dollars per unit, but instead, total fixed and total variable costs are described as a fractions of revenue.

Depreciable assets are divided between fixed and variable according to the input parameter FCA, "fixed part of costs and assets." Inventories, cash, and receivables are classified as variable assets. 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. All other costs are variable, 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:

$$EC.F = (1-T) * TC.F + A.F * ER * ECC,$$

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 (variable) 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:

$$EC.Q = 1 - EC.F - T - EP * ER * A : R ,$$

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 1993 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 two 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" panel 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 (1993 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:

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

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

$$\text{Pre-interestCost} = PIC = TC - IC ,$$

$$\text{Pre-taxCost} = PTC = TC ,$$

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

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

$$\text{Equity} = EQ = ER * A ,$$

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

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

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:

$$Q.B = Q * LCC^{(1/\mu + 1)}$$

$$P.B = (\mu + 1) * EC.BQ ,$$

$$R.B = Q.B * P.B ,$$

$$UVC.B = UVC + DVC.B ,$$

$$VCGS.B = UVC.B * Q.B ,$$

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

$$1X \text{ interest} = X1I.B = LAB * DR * I * LTC ,$$

$$1X \text{ equity cost} = X1E.B = LAB * ER * ECC ,$$

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

$$IC.B = I * DR * (A.B - LAB) - C : R * R.B * (I - ICASH) ,$$

$$PIC.B = TC.B + X1D.B - IC.B ,$$

$$PTC = TC.B + X1D.B + X1I.B ,$$

$$NI = R - TC - TAX - LCC.B - LEE.B , \text{ and}$$

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

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 (μ) for the demand function is set to one. Setting μ 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

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 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 Value Line, Standard and Poor's, Moody's, and publicly available 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 eight 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.

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.

Equity cost of capital. This is the rate of return expected by equity shareholders. This figure is in *real* term, 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 conventional 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 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 *mb* Y%. This response is expected to die out within a few years, and Y% should be less than 20% when SRPR is used.

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) 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 use of a product given in kilowatt hours per year (kWh/y) or million BTUs per year. 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.

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.

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 1987 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 dryers account for 79% of all clothes dryer 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 dishwasher 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.

The manufacturer markup listed 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 the manufacturer price is calculated from the economic markup, which is a markup over *economic* variable costs.* Thus, prices at different standards levels do not exactly reflect the manufacturer cost times the manufacturer markup.

Initial prices. This input is the 1987 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 1987 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%.L).

Financial inputs

Rates of financial costs:

After-tax equity cost of capital. This input is explained in the Control Panel section of C.2.4.

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.

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

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 which 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 standard's 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.2.4.

Fixed part of one-time capital cost. This input is explained in the Control Panel section of C.2.4.

Other financial inputs:

Economic profit. This input is explained in the Control Panel section of C.2.4.

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 which 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

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 ROE.

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 1996 values if the 1990 standards are in effect, but if no new 1993 standards are implemented. The long-run numbers are the model's estimates for these variables when new 1993 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 ROE are primary measures of a company's financial performance. In LBL-MIM, net income is calculated in the Accounting Summary.

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.

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.

ROE. See the Control Panel section above for a description of ROE.

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.

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.2.4) for a more complete description of each of these outputs.

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 LCC 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, eg., standard, top-loading clothes washer. 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 manufacturer selling prices for each product class at each standards level. These manufacturer 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 is 1.46 for all of the product classes analyzed in this TSD). Retail prices are given in 1987 dollars.

C.3 INPUT DATA AND DATA DEVELOPMENT FOR DISHWASHERS, CLOTHES WASHERS, AND CLOTHES DRYERS

The LBL-MIM input data for the dishwasher, clothes washer, and clothes dryer model runs are described together. Most of the input data are the same for each industry, because these products are often grouped in the same division of a larger corporation. Special note is made when the data differ for one of the products.

C.3.1 Engineering Cost Data

The source of the engineering data for dishwashers, clothes washers, and clothes dryers is the Engineering Analysis described in Chapter 3. The data come from manufacturers of these products and have been reviewed by industry consultants. The engineering data used as inputs to the model consist of several components:

- 1) The incremental unit variable cost incurred by the manufacturer for each of the design options that increases the efficiency of the appliance: this incremental variable cost includes raw materials, direct labor, purchased parts, and increased transportation costs. The incremental variable cost is listed for each design option for each product class;
- 2) The annual unit energy consumption (UEC) associated with each design option for each product class;
- 3) Some of the design options also require additional capital investment in the form of retooling, new tooling, or other capital expenditures. These expenses are listed as one figure for each design option requiring capital expenditures; the single figure covers all of the product classes.

The annual UECs listed in the Engineering module of MIM are based on the estimated actual usage of the appliances and differ from the UEC as determined by the test procedure. The energy used per cycle is the same, but the number of cycles run per year differs. This modification is done because the annual UEC as determined by the test procedure is based on an established number of cycles run per year which differs from current actual usage. LBL-REM provides the estimates of actual appliance usage.

The Engineering Analysis of dishwashers finds that some of the design options not only save energy, but also save water. The MIM dishwasher version takes this fact into account by including the cost of water in the operating cost data. This is done by taking the annual cost of water used at a given design option level and dividing it by the cost of a kilowatt-hour, translating the cost of water into its dollar equivalent in kilowatt-hours. This figure is added to the annual UEC figure for the design option to provide a total annual operating cost figure.

The engineering input data are also listed for each standards level being analyzed. A 1987 calibration case, a 1996 base case using the 1990 NAECA standards, and standard levels 1 through 6, which are the new levels being analyzed. The figures used are exactly the same as those used for the design options, but are calculated for standards levels instead. The engineering data used as inputs to the LBL-MIM are listed on the engineering data page of the model. The actual data are listed there rather than here since there are several tables of data for each product type. For a thorough description of the collection and meaning of the engineering data, see the Engineering Analysis.

C.3.2 Industry Market Data

Industry Shipments

These data include annual industry shipments for the 1987 calibration case, the 1996 base case (using the 1990 standards), and the 1996 shipments for each of the standards levels. The 1987 shipments figure comes from the LBL-REM. The 1987 shipments figures used are: 3.5 million units for dishwashers, 5.6 million units for clothes washers, and 4.0 million units for clothes dryers. All of the 1996 estimates come from the LBL-REM.

Elasticities

Price and operating cost elasticities determine the effect on shipments of changes in appliance price and operating cost. For dishwashers, the price elasticity is estimated to be -0.50 and the operating cost elasticity -0.125. For clothes washers, the price elasticity is estimated to be -0.30 and the operating cost elasticity -0.055. For clothes dryers, the price elasticity is estimated to be -0.40 and the operating cost elasticity -0.257. The source of these elasticities is the ORNL Engineering-Economic Model of Residential Energy Use. Because these elasticities are very important, a sensitivity analysis using different elasticities is done.

Product Class Market Share

Each of the product classes has a share of the total market for the product type, and the market share, or unit sales, for each product class is an input to the model. For dishwashers, standard dishwashers have a product class market share of 37%, while water-heating dishwashers have a market share of 63%. Standard clothes washers have a market share of 57%, while large-size clothes washers have a market share of 43%. Standard electric dryers have a market share of 79%, while gas dryers have a market share of 21%. The product class market share estimates come from the LBL-REM.

Markups

At times, manufacturers charge different markups over variable cost for different product classes, resulting in different profit margins for different product classes. However, for the products being analyzed, research by the Manufacturer Analysis team and conversations with industry consultants show that manufacturers use the same markups on different product types within the product class. The markup from manufacturer cost to manufacturer selling price is estimated to be approximately 1.37 for dishwashers, clothes washers, and clothes dryers.

Within each product type there are a variety of models that range from low-end models with only basic features to high-end models that have many additional features, and manufacturer markups vary from the low-end models to the high-end models. The manufacturer markup of 1.37 is for a mid-range or "average" model.

The manufacturer markup described above 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 the manufacturer price is calculated from the economic markup, which is a markup over *economic* variable costs.* Thus, prices at different standards levels do not exactly reflect the manufacturer cost times the manufacturer markup.

Initial Prices

The 1987 baseline manufacturer's selling price is used as a base to which are added incremental costs of reaching the higher efficiency levels. The unit price quoted for each product class refers to the most inexpensive, fewest-frills model produced by the manufacturer. The baseline manufacturing price for standard dishwashers is \$206, for water-heating dishwashers the price is \$226, for standard clothes washers the price is \$260, for large clothes washers the price is \$301, for electric clothes dryers the price is \$206, and for gas clothes dryers the price is \$238. The source of the baseline manufacturer's price for each product class is research by the Engineering Analysis team with review by industry consultants.

Energy Price

This figure is the ratio of the price of a 1987 kWh to a 1996 kWh. The ratio used in the model is 1. The source is the LBL-REM. Industry market data appear on the Cost, Sales, and Revenues page of the model.

C.3.3 Financial Inputs

The financial inputs for dishwashers, clothes washers, and clothes dryers are summarized in Tables C.5 through C.9

Table C.5. Rates of Financial Costs

Variable	Value	Source
After-tax equity cost of capital*	6.8%	MIM calc. from public financial data†
Interest rate on debt*	2.5%	MIM calc. from public financial data
Interest lost on cash*	1.0%	MIM calc. from public financial data
Rate of depreciation	17.7%	Public financial data
Tax rate	34.0%	Tax law

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

† Public financial data include data from Value Line, Standard and Poors, Moody's, individual company annual reports, and economic reports

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

Table C.6. Assets and Costs as a Percent of Revenue

Variable	Value	Source
Cash	4.6%	Public financial data
Inventory and receivables	30.7%	Public financial data
Net depreciable assets	15.1%	Public financial data
General and administrative expenses	13.9%	Public financial data
Engineering expense	1.2%	Public financial data and industry sources‡

‡ Industry sources include consultants under contract to LBL and information from meetings with dishwasher, clothes washer and clothes dryer manufacturing industry consultants.

Table C.7. Fixed, Variable, and Revenue-Related Cost Split

Variable	Value	Source
Fixed part of all costs and depr. assets	10.0%	Industry sources
Fixed part of one-time capital costs	15.0%	Industry sources
Economic profit:	0.0%	MIM est. from financial data
Debt/equity ratio	112.6%	Public financial data
Markup on typical model:	1.37	Industry sources
Ratio of highest to lowest markup:	1.00	Industry sources

Table C.8. One-Time Costs

Variable	Value	Source
One-time capital cost's life	8 years	Industry sources
One-time capital cost's tax life	8 years	MIM calculation
Percent additional 1-X capital	100%	MIM estimate
Age of replaced capital	6 years	Public financial data

Table C.9. Expenditure Schedule
Fraction Expended

	Year Before Standard			
	-3.5	-2.5	-1.5	-0.5
Capital cost	0	0.25	0.50	0.25

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

C.4.1 LBL-MIM OUTPUTS SHOWING THE PRIMARY SCENARIO

C.4.1 Dishwasher Version of MIM

Control Panel

Panel	Scenario: Primary	Standard Level - 2
DISHWASHER	Input	Vari- Progrm
CONTROL FACTORS	Value Cntrl	ation Value Name
Price Elasticity	-0.500 0.00	50% -0.500 IPE
Operating Cost Elasticity	-0.125 0.00	80% -0.125 ICE
Equity Cost of Capital	0.068 0.00	10% 0.068 ECC
Economic Profit	0.000 0.00	0.010 0.000 EP
L-R Fixed part of Costs & Assets	0.100 0.00	50% 0.100 FCA
L-R Fixed Part of 1-X Cap Cost	0.150 0.00	60% 0.150 FIX
One-Time Capital Costs	2.627 0.00	20% 2.627 CC.L
Unit Variable Cost Increase	\$8.30 0.00	20% 8.296 dVC.L
Short Run Price Response to Demand	0.034 0.00	232% 0.034 SRPR

	NAECA	NEW	PRVIOUS	NEW
SUMMARY	BASE	L-RUN	CHANGE	S-RUN
Shipments	0.70	0.70	-0.19%	0.70
Price	\$218.28	\$226.61	3.82%	\$226.60
Revenue (in \$M)	152.72	158.24	3.62%	158.32
Net Income	2.46	2.47	0.39%	2.41
ROE	6.80%	6.72%	-0.08%	6.56%

03/06/89 16:16 Trys - 104.00

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.1 Dishwasher Version of MIM

The Monte Carlo Module

Monte Carlo determination of Standard Errors of Estimates.

Secnds/iteration = 3.17 time

Iterations to go = 0.00 nn

DISHWASHER

Sample Size = 64.00

		%dQ	%dP	%dR	%dNI	dROE.L	dROE.S
curr forms	Value	-0.19%	3.82%	3.62%	0.39%	-0.08%	-0.24%
	Means	-0.00%	7.39%	7.39%	12.22%	0.69%	0.53%
	Std. Dev	0.00%	1.46%	1.46%	10.21%	0.60%	0.60%
History Range Name Is Carlo	History	-0.00	0.07	0.07	0.05	0.00	0.00
		-0.00	0.08	0.08	0.10	0.01	0.01
	Range	-0.00	0.10	0.10	0.08	0.00	0.00
	Name	-0.00	0.08	0.08	0.13	0.01	0.01
	Is	-0.00	0.08	0.08	0.06	0.00	0.00
	Carlo	-0.00	0.08	0.08	0.10	0.01	0.00
		-0.00	0.07	0.07	0.12	0.01	0.00
		-0.00	0.08	0.08	0.07	0.00	0.00
		-0.00	0.11	0.11	0.20	0.01	0.01
		-0.00	0.07	0.07	0.17	0.01	0.01
		-0.00	0.06	0.06	0.04	0.00	0.00
		-0.00	0.09	0.09	0.07	0.00	0.00
		-0.00	0.10	0.10	0.33	0.03	0.02
		-0.00	0.07	0.07	0.07	0.00	0.00
		-0.00	0.05	0.05	0.05	0.00	0.00
		-0.00	0.05	0.05	0.03	0.00	-0.00
		-0.00	0.07	0.07	0.04	0.00	-0.00
		-0.00	0.08	0.08	0.07	0.00	0.00
		-0.00	0.06	0.06	0.07	0.00	0.00
		-0.00	0.07	0.07	0.10	0.01	0.01
		-0.00	0.09	0.09	0.54	0.02	0.02
		-0.00	0.07	0.07	0.13	0.01	0.01
		-0.00	0.05	0.05	0.02	0.00	-0.00
		-0.00	0.06	0.06	0.12	0.01	0.00
		-0.00	0.07	0.07	0.06	0.00	0.00
		-0.00	0.09	0.09	0.26	0.02	0.02
		-0.00	0.10	0.10	0.60	0.03	0.03
		-0.00	0.05	0.05	0.03	0.00	-0.00
		-0.00	0.08	0.08	0.24	0.01	0.01
		-0.00	0.09	0.09	0.11	0.01	0.00
		-0.00	0.07	0.07	0.22	0.01	0.01
		-0.00	0.07	0.07	0.10	0.00	0.00
		-0.00	0.09	0.09	0.14	0.01	0.01
		-0.00	0.07	0.07	0.19	0.01	0.01
		-0.00	0.07	0.07	0.05	0.00	0.00
		-0.00	0.07	0.07	0.10	0.01	0.00
		-0.00	0.08	0.08	0.13	0.01	0.01
		-0.00	0.08	0.08	0.11	0.01	0.00

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.1 Dishwasher Version of MIM

The Accounting Module

ACCOUNTING SUMMARY

DISHWASHER

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

	1987	BASE '96	NEW '96	CHANGE
Revenue	152.39	152.72	158.24	3.6%
Expenses				
Cost of Goods Sold	111.23	111.55	116.75	4.7%
Selling & G & A	29.77	29.76	29.71	-0.2%
Engineering	2.57	2.57	2.56	-0.2%
Depreciation	4.18	4.18	4.18	NA
1-X Depreciation	0.00	0.01	0.33	NA
Total Expenses	147.75	148.08	153.54	3.7%
Earnings Before Interest & Taxes	4.63	4.64	4.68	1.0%
Interest	0.91	0.91	0.93	1.5%
Earnings Before Taxes	3.72	3.73	3.76	0.9%
Taxes	1.27	1.27	1.29	1.8%
Net Income	2.46	2.46	2.47	0.4%
Gross Margin	27.01%	26.95%	26.22%	-2.73%
Return on Sales	1.61%	1.61%	1.56%	-3.1%
Total Assets	76.80	76.83	78.07	1.6%
Return on Assets (w/intrst taxed)	3.98%	3.98%	3.94%	-0.0
Equity	36.13	36.14	36.72	1.6%
Return on Equity	6.80%	6.80%	6.72%	-0.1

ECONOMIC ANALYSIS

	1987	BASE '96	NEW '96	CHANGE
INCOME				
Shipments	0.70	0.70	0.70	-0.2%
Price	\$217.69	\$218.28	\$226.61	3.8%
Revenue	152.39	152.72	158.24	3.6%
EXPENSE (W/ INTEREST)				
Fixed Costs	15.24	15.24	15.24	0.0%
Variable Costs (w/ Q)	133.42	133.74	138.89	3.9%
Total Expenses	148.66	148.97	154.13	3.5%
ASSETS				
Cash	7.01	7.01	6.99	-0.2%
Inventories	46.78	46.76	46.67	-0.2%
Depreciable	23.01	23.07	24.41	5.8%
Total Assets	76.80	76.83	78.07	1.6%

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LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.1 Dishwasher Version of MIM

The Engineering Inputs Module

Inc ement in Additional UVC by Level and Class														
	Base	Food	FMotor	Fill	C	4	5	6	7	8	9	10	11	12
STD	0	7	4	8	0	0	0	0	0	0	0	0	0	0
WAT-HT	0	7	4	8	0	0	0	0	0	0	0	0	0	0
CMPCT	0	7	4	8	0	0	0	0	0	0	0	0	0	0
VCS.E Additional UVC. (Above Level 0 cost)														
CLS	0	1	2	3	4	5	6	7	8	9	10	11	12	
0.00	0	7	11	19	19	19	19	19	19	19	19	19	19	19
1.00	0	7	11	19	19	19	19	19	19	19	19	19	19	19
2.00	0	7	11	19	19	19	19	19	19	19	19	19	19	19
Water costs/yr														
STD	5.65	4.53	4.53	4.38	\$/KwHr: 0 07									
WAT-HT	5.29	4.22	4.22	4.12										
CMPCT	3.77	2.99	2.99	2.90										
Water costs/yr converted to KwHr/Yr (cost/yr)/(\$/kwHr)														
STD	82	66	66	64	64	64	64	64	64	64	64	64	64	64
WAT-HT	77	61	61	60	60	60	60	60	60	60	60	60	60	60
CMPCT	55	43	43	42	60	60	60	60	60	60	60	60	60	60
KWH.PRINT														
Kw Hrs /Yr														
	0	1	2	3	4	5	6	7	8	9	10	11	12	
STD	934	779	761	742	742	742	742	742	742	742	742	742	742	742
WAT-HT	885	740	722	705	705	705	705	705	705	705	705	705	705	705
CMPCT	660	554	538	525	525	525	525	525	525	525	525	525	525	525
Total Operating Costs (energy + water)														
KWS.E	0	1	2	3	4	5	6	7	8	9	10	11	12	
STD	1016	845	827	806	806	806	806	806	806	806	806	806	806	806
WAT-HT	962	801	783	764	764	764	764	764	764	764	764	764	764	764
CMPCT	715	597	581	567	585	585	585	585	585	585	585	585	585	585
Capital cost / unit / 7														
	0	1	2	3	4	5	6	7	8	9	10	11	12	
STD	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WAT-HT	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CMPCT	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Additional Capital Cost in \$M (Above Level 0 Cost) (FORK at 10,11)														
	0	1	2	3	4	5	6	7	8	9	10	11	12	
STD	0	1	1	1	1	1	1	1	1	1	1	1	1	1
WAT-HT	0	2	2	2	2	2	2	2	2	2	2	2	2	2
CMPCT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCEE.E														
	0	4	4	4	4	4	4	4	4	4	4	4	4	4
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MxCC														

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.1 Dishwasher Version of MIM

The Standards Levels Module

Levin	LEV.0	LEV.B	LEV.L	Eng: 0	3	Emax
	-1	0	2	REM: -1	3	Smax
	i	1	1	1 --> Stndrds	0 --> Eng.	
	S E	S E.B	S E.L	Esc - QUIT		

VCS.R	Additional	UVC by	Level	and	Class.	(Above Base cost.)
LEVEL -->	-1-1987	0-1996	1	2	3	4
STD	3.17	3.72	8.32	11.47	18.75	18.75
WAT-HT	3.17	3.72	8.32	11.47	18.75	18.75
CMFCT	3.17	3.72	8.32	11.47	18.75	18.75

KWS.R	Kw Hrs /Yr
LEVEL -->	-1-1987 0-1996
STD	792 787 690 678 662 662 662
WAT-HT	751 746 655 642 629 629 629
CMFCT	678 673 593 580 567 567 567

CCEE.R
LEVEL -->
Cumltv CC
Cumltv EE
STD
WAT-HT
CMFCT

CC.87	CCB	CCN	EE.87	EEB	EEN
1.05	1.17	3.68	0.00	0.00	0.00

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.1 Dishwasher Version of MIM

The Costs, Sales, and Revenue Module

Ratio of highest to lowest markup:	ratio	1.00	bb *****
Typical markup over UVC	mid	0.37	aa *****
Size of firm as % of industry	size	0.20	

CALIBRATION CASE (1987)								
	Indst Ship.	Relatv Ship.	Ship.	Firm Price	Rev.			Weighted
		Q%	Q.1	P.1	R.1	m.1	UVC.1	"UVC
STD	1.26	0.36	0.25	205.50	51.79	1.37	150.00	54.00
WAT-HT	2.17	0.62	0.43	226.05	98.11	1.37	165.00	102.30
CMPCT	0.07	0.02	0.01	178.10	2.49	1.37	130.00	2.60

TOTAL S	3.50	100.00%	0.70	\$218	152.39	1.37	100.00%	\$158.90
		Q.CV	Q	P	R		P.CV	UVC

BASE CASE (1996)								
	Change in UVC	Weighted C	Wghtd in UVC	Op Cost Ratio	Weightd OpCst-R	Qi.B	Ri.B	
STD	0.54	0.19	0.27	\$206	0.99	0.36	0.2519	51.91
WAT-HT	0.54	0.34	0.46	\$227	0.99	0.62	0.4338	98.31
CMPCT	0.54	0.01	0.01	\$179	0.99	0.02	0.0140	2.50

0.79	0.54	0.74	\$218	152.72	-0.01	0.6996	152.72
Mark.B	dVC.B	"P.B	Sum(Ri)	OC%.B	"Q.B	"R.B	
dVC.B.CV	100.00%	check=R.B					

NEW STANDARDS CASE (1996)								
	Change in UVC	Weighted C	Wghtd in UVC	% Chng Op Cost	Weightd OpCst-R	Qi.L	Ri.B	
STD	8.30	2.99	4.09	\$214	0.86	0.31	0.2514	53.75
WAT-HT	8.30	5.14	7.05	\$234	0.86	0.53	0.4329	101.47
CMPCT	8.30	0.17	0.23	\$186	0.86	0.02	0.0140	2.60

TOTAL	0.73	8.30	11.37	\$227	157.83	-0.14	0.6983	158.24
	Mark.L	dVC.L0	"P.L	Sum(Ri)	OC%.L	"Q.L	"R.L	
			check=R.L			OC%.L.CV	30.00%	
1987 \$/kwh // 1996 \$/kwh			kw hr	1.00	OC%.B.CV	100.00%		
Price Elasticity (and Coef. of Var.)	IPE.00	-0.50	IPE.CV0	0.50				
Operating Cost Elasticity (and C.V.)	ICE.00	-0.13	ICE.CV0	0.80				
C.V. of change in UVC (dUVC.L)			UVC.CV	20%				

---OUTPUT---			
CC.B0	CC.L0	EE.B0	EE.L0
0.12	2.63	0.00	0.00

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.1 Dishwasher Version of MIM

The Financial Module

FINANCIAL INPUTS

INPUT	NAME	VALUE	NAME	C.V. or Control Factor

RATES of COST				
After Tax Equity Cost of Capital	ECC.0	6.8%	ECC.CV	10%
Interest Rate on Debt	I.0	2.5%	I.CV	100.00%
Interest Lost on Cash	ICash.0	1.0%	ICASH.CV	100.00%
Rate of Depreciation	Dep.0	17.7%		
Tax Rate	T.0	34.0%	T.CV	100.00%
ASSETS and COSTS as a PERCENT of REVENUE				
Cash	C:R.0	4.6%	C:R.CV	100.00%
Inventory & Receivables	IR:R.0	30.7%	IR:R.CV	27.19%
Depreciable Assets	DA:R.0	15.1%	DA:R.CV	36.89%
G & A	G&A.0	13.9%	G&A.CV	100.00%
Engineering	Eng	1.2%		
FIXED / VARIABLE / REV. RELATED COST SPLIT				
Fixed Part of All Costs & Depr Assets	FDA.0	10.0%	FCA.CV	50%
Fixed Part of 1-X Capital Cost	FIX.0	15.0%	FIX.CV	60%
Economic Profit	EP.0	0.0%	EP.CV	1%
Debt to Equity ratio	DER.0	112.6%	DER.CV	43%
Markup on typical model	"mid	37.0%		
Ratio of highest to lowest markup	"ratio	1.00		

OUTPUT

	NAME	VALUE

Depreciation	DRR	2.7%
G&A to Overhead Ratio	G:O	92.1%
Engineering to Overhead Ratio	E:O	7.9%
Debt Ratio	DR	53.0%
Equity Ratio	ER	47.0%
Pre-Tax Equity Cost of Capital*	PECC	10.3%
Weighted Average Cost of Capital	WACC	6.2%
After Tax WACC	ATWACC	4.1%
Return on Equity	ROE	0.068

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

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

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.1 Dishwasher Version of MIM

The One-Time Cost Amortization Module

INPUT-----				
DESCRIPTION	NAME	VALUE		
1-X CAP. COST'S LIFE (YRS)	L.O	8	L.CV	100.00%
1-X CAP. COST'S TAX LIFE (YRS)	TL	8.00		
PERCENT ADDITIONAL 1-X CAP.	%NC	100%		
AGE OF OLD (REPLACED) CAPITAL	Age	6.00		
YEARS BEFORE 1993	3.50	2.50	1.50	0.50
CC SCHEDULE:	0.00	0.25	0.50	0.25
EE SCHEDULE:	0.10	0.40	0.25	0.25
COMPUTATIONS-----				
DESCRIPTION	NAME	VALUE		
Continuous After-Tax WACC	ATR	3.99%		
Weighted CC Lead-Time Factors	0.00	0.28	0.53	0.26
Weighted EE Lead-Time Factors	0.11	0.44	0.27	0.26
Cumulative CC Lead-Time Factors	LTC.O	1.062		
Cumulative EE Lead-Time Factors	LTE	1.077		
exp(-ATR*TL)	EMRT	0.727		
exp(-ATR*L)	EMRL	0.727		
Rate of tax benefit	BN	0.043		
Remaining tax life	RTL	2.00 years		
	LTC.CV	100.00%		
LEVELIZED CC				
Initial Cost		1.000		
Tax Benefit of Straight-Line Depreciation		-0.291		
Savings from not replacing old Capital later		0.000		
Loss of Tax Benefit from old Capital		0.000		
Tax Benefit from 1-X depreciation of old Cap.		0.000		
Present Value of CC:		0.709		
Adjusted for Capital Lead Time		0.753		
LEVELIZED CC FACTOR	CCLF	0.110		
LEVELIZED EE FACTOR	EELF	0.104		
AVERAGE ASSET FACTOR				
Asset Factor for Cap without Tax Benefit	AFB	0.553		
Asset Factor for Tax Benefit	AFC	0.553		
Tax Benefit as fraction of total CC	B.T	0.225		
Average ASSET FACTOR	AAF	0.553		
INPUT-----				
NEW CAP. COST 1987-96 (\$000)	CC.B00	0.12	COEFFICIENTS of VARIATION	
NEW ENGIN. EXP. 1987-96 (\$000)	EE.B	0.00		
NEW CAP. COST: 1996 CHANGE	"CC.L	2.63	20%	CCL.CV
NEW ENGIN. EXP. 1996 CHANGE	"EE.L	0.00	50%	EEL.CV
OUTPUT-----				
	BASE CASE 1996		NEW STNDS 1996	
Levelized 1-X Engineering Cost	LEE.B00	0.00	LEE.L00	0.00
Levelized 1-X Capital Costs	LC.B00	0.01	LC.L00	0.29
Levelized 1-X Assets	LA.B00	0.07	LA.L00	1.45
	LEE.B.CV	100.00%	LEE.L.CV	100.00%

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.1 Dishwasher Version of MIM

The Long-Run Model Module

MODEL	Long-Run DISHWASHER			
1987 CASE		A.F	A.Q	A.R A
Assets -->		0.015	0.489	0.504 77
Costs except taxes		TC.F	TC.Q	TC.R TC
and equity -->		0.100	0.876	0.976 149
		EC.F	EC.Q	EC.R EC
Economic costs -->		0.066	0.594	1.000 152
		Economic Income		EI.R 0.0000
		Markup (mu - 1)		mul 0.1120
		Price Leader's elasticity of demand:		-9.9
BASE 1996		A.BF	A.BQ	A.B
Assets		2.30	106.43	76.83
		TC.BF	TC.BQ	TC.B
Costs except taxes		15.24	191.15	149
		EC.BF	EC.BQ	EC.B
Economic costs		10.13	129.58	153
NEW 1996		A.LF	A.LQ	A.L
Assets		2.30	106.43	78.07
		TC.LF	TC.LQ	TC.L
Costs except taxes		15.24	198.90	154
		EC.LF	EC.LQ	EC.L
Economic costs		10.17	135.03	156
Assets	-----1987-----	---BASE 1996----	----	NEW 1996----
Shipments	"Q 0.70	Q.B 0.70	Q.L 0.70	
Price	"P \$217.69	P.B \$218.28	P.L \$226.61	
Revenue	"R 152.39	R.B 152.72	R.L 158.24	
Unit Var. Cost	"UVC \$158.90	UVC.B \$159.44	UVC.L \$167.20	
V. Cost Goods	VCGS 111.23	VCGS.B 111.55	VCGS.L 116.75	
1X depreciation		X1D.B 0.01	X1D.L 0.33	
1X interest		X1I.B 0.00	X1I.L 0.02	
1X equity cost		X1E.B 0.00	X1E.L 0.05	
1X tax benefit		X1T.B -0.00	X1T.L -0.11	
Interest not 1X	IC 0.91	IC.B 0.91	IC.L 0.91	
Pre-intrst cst	PIC 147.75	PIC.B 148.08	PIC.L 153.56	
Pre-tax cst	PTC 148.66	PTC.B 148.99	PTC.L 154.48	
Taxes	TAX 1.27	TAX.B 1.27	TAX.L 1.29	
Net Income	NI 2.46	NI.B 2.46	NI.L 2.47	
Economic Incom	EI 0.00	EI.B 0.00	EI.L -0.03	
Equity	EQ 36.13	EQ.B 36.14	EQ.L 36.72	
Retrn on Equity	"ROE 6.80%	ROE.B 6.80%	ROE.L 6.72%	

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.1 Dishwasher Version of MIM

The Short-Run Model Module

SHORT-RUN ANALYSIS

Short-Run "Supply Elasticity of Price":		SRQE .0	0.034
(Q/P)*dP/dQ			
Standard Error of SRQE		SRQE .SD	0.078
Random Value selected for this run:		"SRQE	0.034
R.S	158	"P.L	\$226.61
UVC.S	\$167.20	"Q.L	0.70
VCGS.S	117		
TC.S	154		
TAX.S	1.40	P=a+bQ	ap bp
NI.S	2.41	0.71	cq dq
A.S	78.07	Q=c+dP	1.07 -0.00
ROA.S	4.41%		
EQ.S	36.7%	P.S	226.60
ROE.S	6.56%	Q.s	0.70
		Check P	\$226.60
		Check Q	0.70

Short-Run Assumptions:

The industry installs the long-run optimal level of capital
The industry produces to meet demand at the low short-run price
Inventories are at the long-run level (too high).

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.1 Dishwasher Version of MIM

The Charts Module

CHARTS of Sensitivity and Profit for DISHWASHER

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

Control Variables			Possible Standards Levels				
Name	Value	Changed	1	2	3	4	5
IPE	-0.500	-0.772	0.06%	0.00%	-0.18%		
ICE	-0.125	-0.229	-0.10%	-0.16%	-0.28%		
ECC	0.068	0.075	-0.00%	-0.00%	-0.00%		
EP	0.000	0.010	-0.02%	-0.01%	0.01%		
FCA	0.100	0.154	-0.04%	0.02%	0.18%		
FIX	0.150	0.247	-0.07%	-0.07%	-0.07%		
CC.L	2.627	3.191	-0.02%	-0.02%	-0.02%		
dVC.L	5.146	6.250	0.04%	0.07%	0.13%		
	0.034	0.094					
	Vn	Vc					

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

Level	Engin	Standrds
1	-0.38%	-0.17%
2	-0.27%	-0.08%
3	-0.00%	0.17%
4		
5		
6		
7		
8		
9		
10		
11		
12		

C.4.2 LBL-MIM OUTPUTS SHOWING THE PRIMARY SCENARIO

C.4.2 Clothes Washer Version of MIM

Control Panel

Panel	Scenario: Primary		Standard Level - 2		
CLOTHES WASHER	Input		Vari-	Progrm	
CONTROL FACTORS	Value	Cntrl	ation	Value	Name
Price Elasticity	-0.300	0.00	50%	-0.300	IPE
Operating Cost Elasticity	-0.055	0.00	80%	-0.055	ICE
Equity Cost of Capital	0.068	0.00	10%	0.068	ECC
Economic Profit	0.000	0.00	0.010	0.000	EP
L-R Fixed part of Costs & Assets	0.100	0.00	50%	0.100	FCA
L-R Fixed Part of 1-X Cap. Cost	0.150	0.00	60%	0.150	FIX
One-Time Capital Costs	3.583	0.00	20%	3.583	CC.L
Unit Variable Cost Increase	\$13.11	0.00	20%	13.113	dVC.L
Short Run Price Response to Demand	0.071	0.00	259%	0.071	SRPR

SUMMARY	NAECA	NEW	CHANGE	PRVIOUS	NEW
	BASE	L-RUN		CHANGE	S-RUN
Shipments	1.12	1.12	-0.60%	-0.60%	1.12
Price	\$275.81	\$288.17	4.48%	4.48%	\$288.13
Revenue (in \$M)	309.76	321.69	3.85%	3.85%	323.03
Net Income	4.87	5.06	4.06%	4.06%	5.01
ROE	6.64%	6.87%	0.23%	0.23%	6.81%

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LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.2 Clothes Washer Version of MIM

The Monte Carlo Module

Monte Carlo determination of Standard Errors of Estimates.

Secnds/iteration -	3.04	time
Iterations to go -	0.00	nn
CLOTHES WASHER	Sample Size -	25.00

		%dQ	%dP	%dR	%dNI	dROE.L	dROE.S
curr	Value	-0.60%	4.48%	3.85%	4.06%	0.24%	0.16%
forms	Means	-0.80%	8.19%	7.31%	4.62%	0.11%	-0.05%
	Std. Dev	0.60%	2.02%	1.35%	5.01%	0.34%	0.35%
	History	-0.00	0.07	0.07	0.02	-0.00	-0.00
		-0.01	0.10	0.09	0.05	0.00	-0.00
	Range	-0.00	0.06	0.06	0.01	-0.00	-0.00
	Name	-0.01	0.09	0.08	0.02	0.00	-0.00
	Is	-0.00	0.06	0.06	0.04	0.00	0.00
	Carlo	-0.01	0.10	0.08	0.05	0.00	-0.00
		-0.01	0.09	0.08	-0.01	-0.00	-0.01
		0.00	0.05	0.05	0.01	-0.00	-0.00
		-0.01	0.09	0.08	0.05	0.00	-0.00
		-0.00	0.06	0.06	-0.01	-0.00	-0.00
		-0.02	0.12	0.10	0.11	0.01	-0.01
		-0.01	0.10	0.09	0.14	0.01	0.01
		-0.01	0.08	0.07	0.03	0.00	-0.00
		-0.02	0.12	0.10	0.15	0.01	0.01
		-0.01	0.10	0.08	0.09	0.01	0.00
		-0.01	0.08	0.07	0.03	-0.00	-0.00
		-0.00	0.07	0.06	-0.03	-0.00	-0.00
		-0.00	0.07	0.07	0.05	0.00	0.00
		-0.01	0.08	0.07	0.03	0.00	0.00
		-0.01	0.09	0.08	0.08	0.00	0.00
		-0.01	0.09	0.08	0.13	0.00	0.00
		-0.00	0.06	0.06	-0.02	-0.00	-0.00
		-0.00	0.07	0.06	0.03	0.00	-0.00
		-0.01	0.10	0.08	0.11	0.01	0.00
		0.00	0.05	0.05	-0.02	-0.00	-0.00

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.2 Clothes Washer Version of MIM

The Accounting Module

ACCOUNTING SUMMARY

CLOTHES WASHER

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

	1987	BASE '96	NEW '96	CHANGE
Revenue	307.26	309.76	321.69	3.9%
Expenses				
Cost of Goods Sold	224.28	226.69	238.18	5.1%
Selling & G & A	60.02	60.13	59.88	-0.4%
Engineering	5.18	5.19	5.17	-0.4%
Depreciation	8.44	8.44	8.44	NA
1-X Depreciation	0.00	0.09	0.45	NA
Total Expenses	297.92	300.53	312.11	3.9%
Earnings Before Interest & Taxes	9.34	9.22	9.55	3.5%
Interest	1.84	1.85	1.85	0.1%
Earnings Before Taxes	7.50	7.38	7.70	4.3%
Taxes	2.55	2.51	2.63	4.9%
Net Income	4.95	4.87	5.06	4.1%
Gross Margin	27.01%	26.82%	25.96%	-3.21%
Return on Sales	1.61%	1.57%	1.57%	0.2%
Total Assets	154.86	155.67	156.35	0.4%
Return on Assets (w/intrst taxed)	3.98%	3.91%	4.02%	0.1
Equity	72.84	73.22	73.54	0.4%
Return on Equity	6.80%	6.64%	6.87%	0.2

ECONOMIC ANALYSIS

	1987	BASE '96	NEW '96	CHANGE
INCOME				
Shipments	1.12	1.12	1.12	-0.6%
Price	\$274.34	\$275.81	\$288.17	4.5%
Revenue	307.26	309.76	321.69	3.9%
EXPENSE (W/ INTEREST)				
Fixed Costs	30.73	30.73	30.73	0.0%
Variable Costs (w/ Q)	269.03	271.56	282.79	4.1%
Total Expenses	299.76	302.29	313.51	3.7%
ASSETS				
Cash	14.13	14.17	14.09	-0.6%
Inventories	94.33	94.59	94.02	-0.6%
Depreciable	46.40	46.91	48.24	2.8%
Total Assets	154.86	155.67	156.35	0.4%

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LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.2 Clothes Washer Version of MIM

The Engineering Inputs Module

Increment in Additional UVC by Level and Class													
	Base	Rinse	Therm	Motor	Plast	5	6	7	8	9	10	11	12
TOP-S	0	0	13	4	5	0	0	0	0	0	0	0	0
TOP-L	0	0	13	4	5	0	0	0	0	0	0	0	0
TOP-C	0	0	13	4	5	0	0	0	0	0	0	0	0

VCS.E	Additional UVC (Above Level 0 cost.)												
CLS	0	1	2	3	4	5	6	7	8	9	10	11	12
0.00	0	0	13	17	22	22	22	22	22	22	22	22	22
1.00	0	0	13	17	22	22	22	22	22	22	22	22	22
2.00	0	0	13	17	22	22	22	22	22	22	22	22	22

KWH.PRINT

Kw Hrs /Yr													
KWS.E	0	1	2	3	4	5	6	7	8	9	10	11	12
TOP-S	1019	814	761	747	743	743	743	743	743	743	743	743	743
TOP-L	1394	1102	1027	1015	1010	1010	1010	1010	1010	1010	1010	1010	1010
TOP-C	790	631	590	579	576	576	576	576	576	576	576	576	576

Capital cost / unit / 7													
	0	1	2	3	4	5	6	7	8	9	10	11	12
TOP-S	0.0	0.0	0.4	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOP-L	0.0	0.0	0.4	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOP-C	0.0	0.0	0.4	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Additional Capital Cost in \$M (Above Level 0 Cost) (FORK at 10,11)													
	0	1	2	3	4	5	6	7	8	9	10	11	12
TOP-S	0	0	2	2	6	6	6	6	6	6	6	6	6
TOP-L	0	0	1	1	4	4	4	4	4	4	4	4	4
TOP-C	0	0	0	0	1	1	1	1	1	1	1	1	1

CCEE.E													
	0	0	3	3	11	11	11	11	11	11	11	11	11
	0	0	0	0	0	0	0	0	0	0	0	0	0
MxCC													

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.2 Clothes Washer Version of MIM

The Standards Levels Module

Levin	LEV.0	LEV.B	LEV.L	Eng:	0	4	Emax
	-1	0	2	REM:	-1	4	Smax
	1	1	1	1 -->	Stndrds	0 -->	Eng.
	S E	S E.B	S E.L	Esc	-	QUIT	

VCS.R	Additional UVC by Level and Class. (Above Base cost.)						
LEVEL -->	-1-1987	0-1996	1	2	3	4	5
TOP-S	0.00	1.59	1.88	13.11	16.89	21.60	0.00
TOP-L	0.00	1.59	1.88	13.11	16.89	21.60	0.00
TOP-C	0.00	1.59	1.88	13.11	16.89	21.60	0.00

KWS.R	Kw Hrs /Yr						
LEVEL -->	-1-1987	0-1996	1	2	3	4	5
TOP-S	964	889	825	760	747	743	0
TOP-L	1315	1209	1118	1026	1015	1010	0
TOP-C	747	689	639	589	579	576	0

CCEE.R							
LEVEL -->	-1-1987	0-1996	1	2	3	4	5
Cumltv CC	0.00	0.72	0.79	3.58	3.58	10.98	0.00
Cumltv EE	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	1987	1996	NEW96	1987	1996	NEW96	
	VC87	VCB	VCN	KW87	KWB	KWN	
TOP-S	0.00	1.59	13.11	963.73	888.64	759.97	
TOP-L	0.00	1.59	13.11	1315.27	1208.85	1026.03	
TOP-C	0.00	1.59	13.11	747.13	688.90	589.20	

	CC.87	CCB	CCN	EE.87	EEB	EEN	
	0.00	0.72	3.58	0.00	0.00	0.00	

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.2 Clothes Washer Version of MIM

The Costs, Sales, and Revenue Module

Ratio of highest to lowest markup: ratio 1.00 bb *****
 Typical markup over UVC (TF-A) mid 0.37 aa *****
 Size of firm as % of industry size 0.20

CALIBRATION CASE (1987)								
	Indst Ship.	Relatv Ship.	Ship.	Firm Price	Rev.			Weighted
		Q%	Q.1	P.1	R.1	m.1	UVC.1	"UVC
TOP-S	3.08	0.55	0.62	260.30	160.34	1.37	190.00	104.50
TOP-L	2.24	0.40	0.45	301.40	135.03	1.37	220.00	88.00
TOP-C	0.28	0.05	0.06	212.35	11.89	1.37	155.00	7.75

TOTAL S 5.60 100.00% 1.12 \$274 307.26 1.37 100.00%\$200.25
 Q.CV Q P R P.CV UVC

BASE CASE (1996)								
	Change in UVC	Weighted C	Wghtd d P	Pi.B	Op Cost Ratio	Weighted OpCst-R	Qi.B	Ri.B
TOP-S	1.59	0.87	1.20	\$262	0.92	0.51	0.6177	161.69
TOP-L	1.59	0.64	0.87	\$303	0.92	0.37	0.4492	136.06
TOP-C	1.59	0.08	0.11	\$214	0.92	0.05	0.0562	12.01

0.67 1.59 2.18 \$276 309.76 -0.08 1.1231 309.76
 Mark.B dVC.B "P.B Sum(Ri) OC%.B "Q.B "R.B
 dVC.B.CV 100.00% check=R.B

NEW STANDARDS CASE (1996)								
	Change in UVC	Weighted C	Wghtd d P	Pi.L	% Chng Op Cost	Weighted OpCst-R	Qi.L	Ri.B
TOP-S	13.11	7.21	9.88	\$273	0.79	0.43	0.6140	167.41
TOP-L	13.11	5.25	7.19	\$314	0.78	0.31	0.4465	140.10
TOP-C	13.11	0.66	0.90	\$225	0.79	0.04	0.0558	12.54

TOTAL 0.69 13.11 17.96 \$288 320.05 -0.21 1.1163 321.69
 Mark.L dVC.LO "P.L Sum(Ri) OC%.L "Q.L "R.L
 check=R.L OC%.L.CV 30%
 1987 \$/kwh // 1996 \$/kwh kwhr 1.00 OC%.B.CV 100%
 Price Elasticity (and Coef. of Var.) IPE.00 -0.30 IPE.CV0 50%
 Operating Cost Elasticity (and C.V.) ICE.00 -0.06 ICE.CV0 80%
 C.V. of change in UVC (dUVC.L) UVC.CV 20%

---OUTPUT---
 CC.B0 CC.L0 EE.B0 EE.L0
 0.72 3.58 0.00 0.00

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.2 Clothes Washer Version of MIM

The Financial Module

FINANCIAL INPUTS

INPUT	NAME	VALUE	NAME	C.V. or Control Factor

RATES of COST				
After Tax Equity Cost of Capital	ECC.0	6.8%	ECC.CV	10%
Interest Rate on Debt	I.0	2.5%	I.CV	100.00%
Interest Lost on Cash	ICash.0	1.0%	ICASH.CV	100.00%
Rate of Depreciation	Dep.0	17.7%		
Tax Rate	T.0	34.0%	T.CV	100.00%
ASSETS and COSTS as a PERCENT of REVENUE				
Cash	C:R.0	4.6%	C:R.CV	100.00%
Inventory & Receivables	IR:R.0	30.7%	IR:R.CV	27.19%
Depreciable Assets	DA:R.0	15.1%	DA:R.CV	36.89%
G & A	G&A.0	13.9%	G&A.CV	100.00%
Engineering	Eng	1.2%		
FIXED AND VARIABLE COST SPLIT				
Fixed Part of All Costs & Depr Assets	FDA.0	10.0%	FCA.CV	50%
Fixed Part of 1-X Capital Cost	F1X.0	15.0%	F1X.CV	60%
OTHER				
Economic Profit	EP.0	0.0%	EP.CV	1%
Debt to Equity ratio	DER.0	112.6%	DER.CV	43%
Markup on typical model	"mid	37.0%		
Ratio of highest to lowest markup	"ratio	1.00		

OUTPUT

	NAME	VALUE

Depreciation	DRR	2.7%
G&A to Overhead Ratio	G:O	92.1%
Engineering to Overhead Ratio	E:O	7.9%
Debt Ratio	DR	53.0%
Equity Ratio	ER	47.0%
Pre-Tax Equity Cost of Capital*	PECC	10.3%
Weighted Average Cost of Capital	WACC	6.2%
After Tax WACC	ATWACC	4.1%
Return on Equity	ROE	0.068

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

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

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.2 Clothes Washer Version of MIM

The One-Time Cost Amortization Module

INPUT-----				
DESCRIPTION	NAME	VALUE		
1-X CAP. COST'S LIFE (YRS)	L.O	8	L.CV	100.00%
1-X CAP. COST'S TAX LIFE (YRS)	TL	8.00		
PERCENT ADDITIONAL 1-X CAP	%NC	100%		
AGE OF OLD (REPLACED) CAPITAL	Age	6.00		
YEARS BEFORE 1993	3.50	2.50	1.50	0.50
CC SCHEDULE:	0.00	0.25	0.50	0.25
EE SCHEDULE:	0.10	0.40	0.25	0.25
COMPUTATIONS-----				
DESCRIPTION	NAME	VALUE		
Continuous After-Tax WACC	ATR	3.99%		
Weighted CC Lead-Time Factors	0.00	0.28	0.53	0.26
Weighted EE Lead-Time Factors	0.11	0.44	0.27	0.26
Cumulative CC Lead-Time Factors	LTC.O	1.062		
Cumulative EE Lead-Time Factors	LTE	1.077		
exp(-ATR*TL)	EMRT	0.727		
exp(-ATR*L)	EMRL	0.727		
Rate of tax benefit	BN	0.043		
Remaining tax life	RTL	2.00 years		
	LTC.CV	100.00%		
LEVELIZED CC				
Initial Cost		1.000		
Tax Benefit of Straight-Line Depreciation		-0.291		
Savings from not replacing old Capital later		0.000		
Loss of Tax Benefit from old Capital		0.000		
Tax Benefit from 1-X depreciation of old Cap.		0.000		
Present Value of CC:		0.709		
Adjusted for Capital Lead Time		0.753		
LEVELIZED CC FACTOR	CCLF	0.110		
LEVELIZED EE FACTOR	EELF	0.104		
AVERAGE ASSET FACTOR				
Asset Factor for Cap without Tax Benefit	AFB	0.553		
Asset Factor for Tax Benefit	AFC	0.553		
Tax Benefit as fraction of total CC	B:T	0.225		
Average ASSET FACTOR	AAF	0.553		
INPUT-----				
NEW CAP. COST 1987-96 (\$000)	CC.B00	0.72	COEFFICIENTS of VARIATION	
NEW ENGIN. EXP. 1987-96 (\$000)	EE.B	0.00		
NEW CAP. COST: 1996 CHANGE	"CC.L	3.58	20%	CCL.CV
NEW ENGIN. EXP. 1996 CHANGE	"EE.L	0.00	50%	EEL.CV
OUTPUT-----				
	BASE CASE 1996		NEW STNDS 1996	
Levelized 1-X Engineering Cost	LEE.B00	0.00	LEE.L00	0.00
Levelized 1-X Capital Costs	LC.B00	0.08	LC.L00	0.39
Levelized 1-X Assets	LA.B00	0.40	LA.L00	1.98
	LEE.B.CV	100.00%	LEE.L.CV	100.00%

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.2 Clothes Washer Version of MIM

The Long-Run Model Module

MODEL	Long-Run CLOTHES WASHER			
1987 CASE		A.F	A.Q	A.R
Assets -->		0.015	0.489	0.504
Costs except taxes and equity -->		TC.F	TC.Q	TC.R
		0.100	0.876	0.976
Economic costs -->		EC.F	EC.Q	EC.R
		0.066	0.594	0.000
		Economic Income		EI.R
		Markup (mu - 1)		mul
		Price Leader's elasticity of demand:		-9.9
BASE 1996		A.BF	A.BQ	A.B
Assets		4.64	134.13	155.67
Costs except taxes		TC.BF	TC.BQ	TC.B
		30.73	241.80	302
Economic costs		EC.BF	EC.BQ	EC.B
		20.44	163.94	309
NEW 1996		A.LF	A.LQ	A.L
Assets		4.64	134.13	156.35
Costs except taxes		TC.LF	TC.LQ	TC.L
		30.73	253.32	314
Economic costs		EC.LF	EC.LQ	EC.L
		20.49	171.78	317
Assets	-----1987-----	---BASE 1996---	-----NEW 1996----	
Shipments	"Q 1.12	Q.B 1.12	Q.L 1.12	
Price	"P \$274.34	P.B \$275.81	P.L \$288.17	
Revenue	"R 307.26	R.B 309.76	R.L 321.69	
Unit Var. Cost	"UVC \$200.25	UVC.B \$201.84	UVC.L \$213.36	
V. Cost Goods	VOGS 224.28	VOGS.B 226.69	VOGS.L 238.18	
1X depreciation		X1D.B 0.09	X1D.L 0.45	
1X interest		X1I.B 0.01	X1I.L 0.03	
1X equity cost		X1E.B 0.01	X1E.L 0.06	
1X tax benefit		X1T.B -0.03	X1T.L -0.15	
Interest not 1X	IC 1.84	IC.B 1.84	IC.L 1.82	
Pre-intrst cst	PIC 297.92	PIC.B 300.53	PIC.L 312.14	
Pre-tax cst	PTC 299.76	PTC.B 302.38	PTC.L 313.99	
Taxes	TAX 2.55	TAX.B 2.51	TAX.L 2.63	
Net Income	NI 4.95	NI.B 4.87	NI.L 5.06	
Economic Incom	EI -0.00	EI.B -0.11	EI.L 0.06	
Equity	EQ 72.84	EQ.B 73.22	EQ.L 73.54	
Retrn on Equity	"ROE 6.80%	ROE.B 6.64%	ROE.L 6.87%	

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.2 Clothes Washer Version of MIM

The Short-Run Model Module

SHORT-RUN ANALYSIS

Short-Run "Supply Elasticity of Price":		SRQE.0	0.071
(Q/P)*dP/dQ			
Standard Error of SRQE		SRQE.SD	0.184
Random Value selected for this run:		"SRQE	0.071
R.S	323	"P.L	\$288.17
UVC.S	\$213.36	"Q.L	1.12
VCGS.S	239		
TC.S	315		
TAX.S	2.82	P=a+bQ	ap 18.22
NI.S	5.01	1.14	cq dq
A.S	156.35	Q=c+dP	1.48 -0.00
ROA.S	4.53%	P.S	288.13
EQ.S	73.54	Q.s	1.12
ROE.S	6.81%	Check P	\$288.13
		Check Q	1.12

Short-Run Assumptions:

The industry installs the long-run optimal level of capital
The industry produces to meet demand at the low short-run price
Inventories are at the long-run level (too high)

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.2 Clothes Washer Version of MIM

The Charts Module

CHARTS of Sensitivity and Profit for CLOTHES WASHER

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

Control Variables			Possible Standards Levels				
Name	Value	Changed	1	2	3	4	5
IPE	-0.300	-0.463	0.10%	0.05%	0.02%	-0.06%	
ICE	-0.055	-0.101	-0.10%	-0.33%	-0.39%	-0.43%	
ECC	0.068	0.075	-0.00%	-0.00%	-0.00%	-0.00%	
EP	0.000	0.010	-0.01%	0.01%	0.02%	0.01%	
FCA	0.100	0.154	-0.12%	0.19%	0.31%	0.51%	
FIX	0.150	0.247	-0.00%	-0.04%	-0.04%	-0.15%	
CC.L	0.787	0.955	-0.00%	-0.01%	-0.01%	-0.04%	
dVC.L	1.878	2.280	0.02%	0.17%	0.22%	0.27%	
	0.071	0.207					
	Vn	Vc					

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

Scenario=Primary

Level	Engin	Stndrds
1	-0.66%	-0.19%
2	-0.12%	0.24%
3	0.09%	0.43%
4	0.23%	0.57%
5		
6		
7		
8		
9		
10		
11		
12		

C.4.3 LBL-MIM OUTPUTS SHOWING THE PRIMARY SCENARIO

C.4.3 Clothes Dryer Version of MIM

Control Panel

Panel	Scenario: Primary			Standard Level - 5		
DRYERS	Input			Vari-	Progrm	
CONTROL FACTORS	Value			ation	Value	Name
Price Elasticity	-0.400	0.00		50%	-0.400	IPE
Operating Cost Elasticity	-0.257	0.00		80%	-0.257	ICE
Equity Cost of Capital	0.068	0.00		10%	0.068	ECC
Economic Profit	0.000	0.00		0.010	0.000	EP
L-R Fixed part of Costs & Assets	0.100	0.00		50%	0.100	FCA
L-R Fixed Part of 1-X Cap. Cost	0.150	0.00		60%	0.150	FIX
One-Time Capital Costs	8.689	0.00		20%	8.689	CC.L
Unit Variable Cost Increase	\$16.58	0.00		20%	16.584	dVC.L
Short Run Price Response to Demand	0.116	0.00		90%	0.116	SRPR
	0.92	0.96	1.14		0.96	0.9994
	NAECA	NEW		PRVIOUS	NEW	
SUMMARY	BASE	L-RUN	CHANGE	CHANGE	S-RUN	
Shipments	0.7982	0.7976	-0.06%	-0.06%	0.80	
Price	\$213.70	\$230.65	7.93%	7.93%	\$230.68	
Revenue (in \$M)	170.57	183.97	7.86%	7.86%	184.37	
Net Income	2.63	3.44	30.87%	30.87%	3.52	
ROE	6.55%	8.10%	1.55%	1.55%	8.34%	

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LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.3 Clothes Dryer Version of MIM

The Monte Carlo Module

Monte Carlo determination of Standard Errors of Estimates.

Secnds/iteration = 3.21 time

Iterations to go = 0.00 nn

Sample Size = 100.00

DRYERS

		%dQ	%dP	%dR	%dNI	dROE.L	dROE.S
curr forms	Value	-0.06%	7.93%	7.86%	30.87%	1.61%	1.79%
	Means	0.38%	8.65%	9.07%	60.95%	3.35%	2.29%
	Std. Dev	0.03%	1.73%	1.76%	27.26%	1.58%	1.51%
History		0.00	0.10	0.10	0.77	0.04	0.03
		0.00	0.08	0.08	0.58	0.03	0.02
	Range	0.00	0.08	0.08	0.42	0.02	0.01
Name		0.00	0.13	0.14	1.65	0.09	0.03
	Is	0.00	0.10	0.10	1.10	0.05	0.04
	Carlo	0.00	0.09	0.09	0.75	0.03	0.01
		0.00	0.10	0.10	0.81	0.03	0.02
		0.00	0.08	0.08	0.26	0.02	0.01
		0.00	0.07	0.08	0.56	0.02	0.01
		0.00	0.10	0.10	0.49	0.03	0.02
		0.00	0.12	0.13	1.13	0.05	0.04
		0.00	0.06	0.07	0.35	0.02	0.01
		0.00	0.08	0.08	0.43	0.02	0.01
		0.00	0.07	0.07	0.33	0.02	0.01
		0.00	0.10	0.10	0.62	0.03	0.02
		0.00	0.08	0.08	0.64	0.02	0.02
		0.00	0.08	0.08	0.52	0.03	0.02
		0.00	0.09	0.09	0.74	0.04	0.03
		0.00	0.07	0.07	0.45	0.02	0.01
		0.00	0.08	0.09	0.40	0.03	0.02
		0.00	0.09	0.10	0.50	0.03	0.02
		0.00	0.09	0.10	0.43	0.02	0.01
		0.00	0.07	0.07	0.34	0.02	0.01
		0.00	0.07	0.07	0.43	0.03	0.02
		0.00	0.07	0.07	0.49	0.02	0.01
		0.00	0.10	0.10	0.71	0.04	0.03
		0.00	0.10	0.10	0.66	0.04	0.03
		0.00	0.06	0.06	0.49	0.02	0.01
		0.00	0.10	0.10	1.10	0.07	0.06
		0.00	0.09	0.09	0.78	0.06	0.04
		0.00	0.09	0.09	0.72	0.04	0.03
		0.00	0.06	0.06	0.45	0.02	0.01
		0.00	0.10	0.10	0.95	0.06	0.05
		0.00	0.08	0.09	0.53	0.03	0.02
		0.00	0.08	0.08	0.79	0.03	0.02
		0.00	0.09	0.09	0.80	0.03	0.02
		0.00	0.07	0.07	0.38	0.02	0.01
		0.00	0.11	0.11	0.68	0.04	0.02

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.3 Clothes Dryer Version of MIM

The Accounting Module

ACCOUNTING SUMMARY

DRYERS

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

	1987	BASE '96	NEW '96	CHANGE
Revenue	168.39	170.57	183.97	7.9%
Expenses				
Cost of Goods Sold	122.92	124.77	135.78	8.8%
Selling & G & A	32.90	33.15	33.21	0.2%
Engineering	2.84	2.86	2.87	0.2%
Depreciation	4.62	4.62	4.62	NA
1-X Depreciation	0.00	0.15	1.09	NA
Total Expenses	163.27	165.56	177.57	7.3%
Earnings Before Interest & Taxes	5.12	5.00	6.34	26.7%
Interest	1.01	1.01	1.06	5.1%
Earnings Before Taxes	4.11	3.99	5.27	32.1%
Taxes	1.40	1.36	1.83	34.5%
Net Income	2.71	2.63	3.44	30.9%
Gross Margin	27.01%	26.85%	26.19%	-2.45%
Return on Sales	1.61%	1.54%	1.87%	21.3%
Total Assets	84.87	85.34	89.68	5.1%
Return on Assets (w/intrst taxed)	3.98%	3.86%	4.62%	0.8
Equity	39.92	40.14	42.18	5.1%
Return on Equity	6.80%	6.55%	8.10%	1.5

ECONOMIC ANALYSIS

	1987	BASE '96	NEW '96	CHANGE
INCOME				
Shipments	0.80	0.80	0.80	-0.1%
Price	\$210.49	\$213.70	\$230.65	7.9%
Revenue	168.39	170.57	183.97	7.9%
EXPENSE (W/ INTEREST)				
Fixed Costs	16.84	16.84	16.84	0.0%
Variable Costs (w/ Q)	147.44	149.24	160.24	7.4%
Total Expenses	164.28	166.08	177.08	6.6%
ASSETS				
Cash	7.75	7.73	7.72	-0.1%
Inventories	51.70	51.58	51.55	-0.1%
Depreciable	25.43	26.03	30.41	16.8%
Total Assets	84.87	85.34	89.68	5.1%

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LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.3 Clothes Dryer Version of MIM

The Engineering Inputs Module

Increment in Additional UVC by Level and Class													
	Base	Temp	Moist	1"	Ins	Rec	Ex	E3	G2	E1	G2	E0	G2
EL-STD	0	8	5	6	24	-24	-10	-8	0	0	0	0	0
GS-STD	0	8	5	6	24	-30	0	0	0	0	0	0	0
EC-120	0	8	5	6	24	-24	-10	-8	0	0	0	0	0
EC-240	0	8	5	6	24	-24	-10	-8	0	0	0	0	0

VCS.E	Additional UVC			(Above Level 0 cost.)									
CLS	0	1	2	3	4	5	6	7	8	9	10	11	12
0.00	0	8	12	18	42	18	8	0	0	0	0	0	0
1.00	0	8	12	18	42	12	12	12	12	12	12	12	12
2.00	0	8	12	18	42	18	8	0	0	0	0	0	0
3.00	0	8	12	18	42	18	8	0	0	0	0	0	0

KWH PRINT

Kw Hrs /Yr													
KWS.E	0	1	2	3	4	5	6	7	8	9	10	11	12
EL-STD	1059	988	933	914	859	914	988	1059	914	914	914	914	914
GS-STD	4.00	3.73	3.52	3.45	3.24	3.52	3.52	3.52	4.00	4.00	4.00	4.00	4.00
EC-120	428	399	377	369	347	369	399	428	347	347	347	347	347
EC-240	474	442	418	409	384	409	442	474	384	384	384	384	384

Capital cost / unit / 7													
	0	1	2	3	4	5	6	7	8	9	10	11	12
EL-STD	0.0	0.5	0.5	0.7	6.0	-6	-1	-1	0.0	0.0	0.0	0.0	0.0
GS-STD	0.0	0.5	0.5	0.7	6.0	-7	0	0	0.0	0.0	0.0	0.0	0.0
EC-120	0.0	0.5	0.5	0.7	6.0	-6	-1	-1	0.0	0.0	0.0	0.0	0.0
EC-240	0.0	0.5	0.5	0.7	6.0	-6	-1	-1	0.0	0.0	0.0	0.0	0.0

Additional Capital Cost in \$M (Above Level 0 Cost) (FORK at 10,11)													
	0	1	2	3	4	5	6	7	8	9	10	11	12
EL-STD	0	2	4	7	31	7	2	0	0	0	0	0	0
GS-STD	0	1	1	2	10	1	1	1	1	1	1	1	1
EC-120	0	0	0	0	1	0	0	0	0	0	0	0	0
EC-240	0	0	0	0	1	0	0	-0	-0	-0	-0	-0	-0

CCEE.E													
	0	3	6	10	43	9	3	1	1	1	1	1	1
	0	0	0	0	0	0	0	0	0	0	0	0	0

MxCC

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.3 Clothes Dryer Version of MIM

The Standards Levels Module

Levl n LEV.0 LEV.B LEV.L Eng 0 7 Emax
 -1 0 5 REM-1 6 Smax
 1 1 1 1 --> Stnd 0 --> Eng.
 S|E S|E.B S|E.L Esc - QUIT

VCS.R Additional UVC by Level and Class. (Above Base cost.)
 LEVEL ->-1-1987 0-1996 1 2 3 4 5 6 7
 EL-STD 0.00 0.00 7.50 12.00 17.90 41.90 17.90 17.90 0.00
 GS-STD 0.00 12.00 12.00 12.00 17.90 41.90 12.00 12.00 0.00
 EC-120 0.00 0.00 7.50 12.00 17.90 41.90 17.90 17.90 0.00
 EC-240 0.00 0.00 7.50 12.00 17.90 41.90 17.90 17.90 0.00

KWS.R Kw Hrs /Yr
 LEVEL ->-1-1987 0-1996 1 2 3 4 5 6 7
 EL-STD 1059 1059 988 933 914 859 914 914 0
 GS-STD 4.00 3.52 3.52 3.52 3.45 3.24 3.52 3.52 0.00
 EC-120 428 428 399 377 369 347 369 369 0
 EC-240 474 474 442 418 409 384 409 409 0

CCEE.R
 LEVEL ->-1-1987 0-1996 1 2 3 4 5 6 7
 Cuml tvCC 0.00 1.19 3.39 5.60 9.52 43.12 8.69 8.69 0.00
 Cuml tvEE 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00

	1987 VC87	1996 VCB	NEW96 VCN	1987 KW87	1996 KWB	NEW96 KWN
EL-STD	0.00	0.00	17.90	1059	1059	914
GS-STD	0.00	12.00	12.00	4.00	3.52	3.52
EC-120	0.00	0.00	17.90	428	428	369
EC-240	0.00	0.00	17.90	474	474	409

CC.87	CCB	CCN	EE.87	EEB	EEN
0.00	1.19	8.69	0.00	0.00	0.00

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.3 Clothes Dryer Version of MIM

The Costs, Sales, and Revenue Module

Ratio of highest to lowest markup:	ratio	1.00	bb	*****
Typical markup over UVC (TF-A)	mid	0.37	aa	*****
Size of firm as % of industry	size	0.20		

CALIBRATION CASE (1987)								
	Indst Ship.	Relatv Ship.	Firm Ship.	Price	Rev.			Weighted
		Q%	Q.1	P.1	R.1	m.1	UVC.1	"UVC
EL-STD	2.92	0.73	0.5840	205.50	120.01	1.37	150.00	109.50
GS-STD	0.89	0.22	0.1784	232.90	41.55	1.37	170.00	37.91
EC-120	0.09	0.02	0.0184	171.25	3.15	1.37	125.00	2.88
EC-240	0.10	0.02	0.0192	191.80	3.68	1.37	140.00	3.36

TOTAL S	4.00	100.00%	0.80	\$210	168.39	1.37	100.00%	\$153.64
		Q.CV	Q	P	R		P.CV	UVC

BASE CASE (1996)								
	Change in UVC	Weighted C	Wghtd in UVC	Op Cost	Weightd Ratio	OpCst-R	Qi.B	Ri.B
			d P	Pi.B				
EL-STD	0.00	0.00	0.00	\$206	1.00	0.73	0.5959	122.45
GS-STD	12.00	2.68	3.67	\$247	0.88	0.20	0.1664	41.14
EC-120	0.00	0.00	0.00	\$171	1.00	0.02	0.0188	3.22
EC-240	0.00	0.00	0.00	\$192	1.00	0.02	0.0196	3.76

0.88	2.68	3.67	\$214	170.57	-0.03	0.80	170.57
Mark.B	dVC.B		"P.B	Sum(Ri)	OC%.B	"Q.B	"R.B
dVC.B.CV	100.00%		chek-R.B				

NEW STANDARDS CASE (1996)								
	Change in UVC	Weighted C	Wghtd in UVC	% Chng Op Cost	Weightd OpCst-R	Qi.L	Ri.B	
			d P	Pi.L				
EL-STD	17.90	13.07	17.90	\$227	0.86	0.63	0.5743	130.50
GS-STD	12.00	2.68	3.67	\$247	0.88	0.20	0.1862	46.09
EC-120	17.90	0.41	0.56	\$193	0.86	0.02	0.0176	3.39
EC-240	17.90	0.43	0.59	\$214	0.86	0.02	0.0187	3.99

TOTAL	0.89	16.58	22.72	\$231	183.97	-0.13	0.80	183.97
	Mark.L	dVC.L0		"P.L	Sum(Ri)	OC%.L	"Q.L	"R.L
1987 \$/kwh // 1996 \$/kwh				kwhr	1.00	OC%.L.CV		30%
Price Elasticity (and Coef. of Var.)				IPE.00	-0.40	OC%.B.CV		100%
Operating Cost Elasticity (and C.V.)				ICE.00	-0.26	ICE.CV0		50%
C.V. of change in UVC (dUVC.L)						UVC.CV		80%
								20%

---OUTPUT---			
CC.B0	CC.L0	EE.B0	EE.L0
1.19	8.69	0.00	0.00

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.3 Clothes Dryer Version of MIM

The Financial Module

FINANCIAL INPUTS

INPUT	NAME	VALUE	NAME	C.V. or Control Factor

RATES of COST				
After Tax Equity Cost of Capital	ECC.0	6.8%	ECC.CV	10%
Interest Rate on Debt	I.0	2.5%	I.CV	100.00%
Interest Lost on Cash	ICash.0	1.0%	CASH.CV	100.00%
Rate of Depreciation	Dep.0	17.7%		
Tax Rate	T.0	34.0%	T.CV	100.00%
ASSETS and COSTS as a PERCENT of REVENUE				
Cash	C.R.0	4.6%	C.R.CV	100.00%
Inventory & Receivables	IR.R.0	30.7%	IR.R.CV	27.19%
Depreciable Assets	DA.R.0	15.1%	DA.R.CV	36.89%
G & A	G&A.0	13.9%	G&A.CV	100.00%
Engineering	Eng	1.2%		
FIXED AND VARIABLE COST SPLIT				
Fixed Part of All Costs & Depr Assets	FDA.0	10.0%	FCA.CV	50%
Fixed Part of 1-X Capital Cost	FIX.0	15.0%	FIX.CV	60%
OTHER				
Economic Profit	EP.0	0.0%	EP.CV	1%
Debt to Equity ratio	DER.0	112.6%	DER.CV	43%
Markup on typical model	"mid	37.0%		
Ratio of highest to lowest markup	"ratio	1.00		

OUTPUT

	NAME	VALUE

Depreciation	DRR	2.7%
G&A to Overhead Ratio	G:O	92.1%
Engineering to Overhead Ratio	E:O	7.9%
Debt Ratio	DR	53.0%
Equity Ratio	ER	47.0%
Pre-Tax Equity Cost of Capital*	PECC	10.3%
Weighted Average Cost of Capital	WACC	6.2%
After Tax WACC	ATWACC	4.1%
Return on Equity	ROE	0.068

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

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

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.3 Clothes Dryer Version of MIM

The One-Time Cost Amortization Module

INPUT-----				
DESCRIPTION	NAME	VALUE		
1-X CAP. COST'S LIFE (YRS)	L.O	8.00	L.CV	100.00%
1-X CAP. COST'S TAX LIFE (YRS)	TL	8.00		
PERCENT ADDITIONAL 1-X CAP	%ANC	100%		
AGE OF OLD (REPLACED) CAPITAL	Age	6.00		
YEARS BEFORE 1993	3.50	2.50	1.50	0.50
CC SCHEDULE:	0.00	0.25	0.50	0.25
EE SCHEDULE:	0.10	0.40	0.25	0.25
COMPUTATIONS-----				
DESCRIPTION	NAME	VALUE		
Continuous After-Tax WACC	ATR	3.99%		
Weighted CC Lead-Time Factors	0.00	0.28	0.53	0.26
Weighted EE Lead-Time Factors	0.11	0.44	0.27	0.26
Cumulative CC Lead-Time Factors	LTC.O	1.062		
Cumulative EE Lead-Time Factors	LTE	1.077		
exp(-ATR*TL)	EMRT	0.727		
exp(-ATR*L)	EMRL	0.727		
Rate of tax benefit	BN	0.043		
Remaining tax life	RTL	2.00 years		
	LTC.CV	100.00%		
LEVELIZED CC				
Initial Cost		1.000		
Tax Benefit of Straight-Line Depreciation		-0.291		
Savings from not replacing old Capital later		0.000		
Loss of Tax Benefit from old Capital		0.000		
Tax Benefit from 1-X depreciation of old Cap.		0.000		
Present Value of CC:		0.709		
Adjusted for Capital Lead Time		0.753		
LEVELIZED CC FACTOR	CCLF	0.110		
LEVELIZED EE FACTOR	EELF	0.104		
AVERAGE ASSET FACTOR				
Asset Factor for Cap without Tax Benefit	AFB	0.553		
Asset Factor for Tax Benefit	AFC	0.553		
Tax Benefit as fraction of total CC	B:T	0.225		
Average ASSET FACTOR	AAF	0.553		
INPUT-----				
NEW CAP. COST 1987-96 (\$000)	CC.B00	1.19	COEFFICIENTS of	
NEW ENGIN. EXP. 1987-96 (\$000)	EE.B	0.00	VARIATION	
NEW CAP. COST: 1996 CHANGE	"CC.L	8.69	20%	CCL.CV
NEW ENGIN. EXP. 1996 CHANGE	"EE.L	0.00	50%	EEL.CV
OUTPUT-----				
	BASE CASE 1996		NEW STNDS 1996	
Levelized 1-X Engineering Cost	LEE.B00	0.00	LEE.L00	0.00
Levelized 1-X Capital Costs	LC.B00	0.13	LC.L00	0.96
Levelized 1-X Assets	LA.B00	0.66	LA.L00	4.81
	LEE.B.CV	100.00%	LEE.L.CV	100.00%

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.3 Clothes Dryer Version of MIM

The Long-Run Model Module

MODEL	Long-Run DRYERS			
1987 CASE	A.F	A.Q	A.R	A
Assets -->	0.015	0.489	0.504	85
Costs except taxes	TC.F	TC.Q	TC.R	TC
and equity -->	0.100	0.876	0.976	164
	EC.F	EC.Q	EC.R	EC
Economic costs -->	0.066	0.594	1.000	168
	Economic Income		EI.R	0.0000
	Markup (mu - 1)		mul	0.1120
	Price Leader's elasticity of demand:			-9.9
BASE 1996	A.BF	A.BQ		A.B
Assets	2.54	102.91		85.34
	TC.BF	TC.BQ		TC.B
Costs except taxes	16.84	186.98		166
	EC.BF	EC.BQ		EC.B
Economic costs	11.21	126.84		170
NEW 1996	A.LF	A.LQ		A.L
Assets	2.54	102.91		89.68
	TC.LF	TC.LQ		TC.L
Costs except taxes	16.84	200.89		178
	EC.LF	EC.LQ		EC.L
Economic costs	11.34	136.89		178
	1.37	1.22		
Assets	-----1987-----	---BASE 1996---	-----NEW 1996----	
Shipments	"Q 0.80	Q.B 0.80	Q.L 0.80	
Price	"P \$210.49	P.B \$213.70	P.L \$230.65	
Revenue	"R 168.39	R.B 170.57	R.L 183.97	
Unit Var. Cost	"UVC \$153.64	UVC.B \$156.32	UVC.L \$170.23	
V. Cost Goods	VCGS 122.92	VCGS.B 124.77	VCGS.L 135.78	
1X depreciation		X1D.B 0.15	X1D.L 1.09	
1X interest		X1I.B 0.01	X1I.L 0.07	
1X equity cost		X1E.B 0.02	X1E.L 0.15	
1X tax benefit		X1T.B -0.05	X1T.L -0.35	
Interest not 1X	IC 1.01	IC.B 1.00	IC.L 1.00	
Pre-intrst cst	PIC 163.27	PIC.B 165.57	PIC.L 177.64	
Pre-tax cst	PTC 164.28	PTC.B 166.58	PTC.L 178.70	
Taxes	TAX 1.40	TAX.B 1.36	TAX.L 1.83	
Net Income	NI 2.71	NI.B 2.63	NI.L 3.44	
Economic Incom	EI 0.00	EI.B -0.10	EI.L 0.57	
Equity	EQ 39.92	EQ.B 40.14	EQ.L 42.18	
Retrn on Equity	"ROE 6.80%	ROE.B 6.55%	ROE.L 8.10%	

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.3 Clothes Dryer Version of MIM

The Short-Run Model Module

SHORT-RUN ANALYSIS

Short-Run "Supply Elasticity of Price":		SRQE.0	0.116
(Q/P)*dP/dQ			
Standard Error of SRQE		SRQE.SD	0.104
Random Value selected for this run:		"SRQE	0.116
R.S	184	"P.L	\$230.65
UVC.S	\$170.23	"Q.L	0.80
VCGS.S	136		
TC.S	177		
TAX.S	2.37	P=a+bQ	203.89
NI.S	3.52	0.83	33.52
A.S	89.68	Q=c+dP	1.16
ROA.S	5.25%		-0.00
EQ.S	42.18	P.S	230.68
ROE.S	8.34%	Q.s	0.80
		Check P	\$230.68
		Check Q	0.80

Short-Run Assumptions:

The industry installs the long-run optimal level of capital
The industry produces to meet demand at the low short-run price
Inventories are at the long-run level (too high).

LBL-MIM UNDER THE PRIMARY SCENARIO

C.4.3 Clothes Dryer Version of MIM

The Charts Module

CHARTS of Sensitivity and Profit for DRYERS

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

Control Variables			Possible Standards Levels						
Name	Value	Changed	1	2	3	4	5	6	7
IPE	-0.400	-0.617	-2.05%	-3.33%	-5.36%	-12.37%	-4.92%	-0.05	
ICE	-0.257	-0.471	3.34%	6.01%	7.08%	8.60%	6.85%	0.07	
ECC	0.068	0.075	-0.01%	-0.01%	-0.02%	-0.08%	-0.02%	-0.00	
EP	0.000	0.010	0.01%	0.01%	0.00%	-0.10%	0.00%	0.00	
FCA	0.100	0.154	0.39%	0.59%	0.89%	1.78%	0.83%	0.01	
FIX	0.150	0.247	-0.04%	-0.08%	-0.14%	-0.50%	-0.13%	-0.00	
CC.L	3.394	4.122	-0.10%	-0.16%	-0.25%	-0.55%	-0.24%	-0.00	
dVC.L	8.504	10.328	-0.88%	-1.19%	-1.80%	-4.09%	-1.65%	-0.02	
	0.116	0.222							
	Vn	Vc							

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

Level	Engin Stndrds	
1	1.22%	1.56%
2	2.65%	2.91%
3	0.74%	0.99%
4	-9.77%	-9.52%
5	1.36%	1.61%
6	1.30%	1.61%
7	-0.28%	
8		
9		
10		
11		
12		

APPENDIX D. ENVIRONMENTAL EFFECTS OF ENERGY CONSERVATION STANDARDS FOR THREE TYPES OF CONSUMER PRODUCTS: DISHWASHERS, CLOTHES WASHERS, AND CLOTHES DRYERS

D.1 INTRODUCTION AND SUMMARY

The environmental impacts resulting from new or amended energy-efficiency standards for dishwashers, clothes washers and clothes dryers as mandated by the National Appliance Energy Conservation Act of 1988 (NAECA) are discussed here. (1) A complete description of the Engineering and Economic Analysis of the proposed standards may be found elsewhere in the Technical Support Document (TSD). All fifteen of the scenarios for product design changes described in the Engineering Analysis of the TSD are analyzed in the environmental assessment in the form of levels of pollutant reduction. Level 1 represents the least amount of pollutant reduction, while higher numbered levels represent increasingly more stringent standards, with correspondingly greater reductions in pollutants. Values for energy savings that result from product design changes are taken from the TSD. These energy savings are based on recent data on actual usage rather than DOE test procedures.

The main environmental concern addressed is emissions from fossil-fueled electricity generation. Each of the design options for dishwashers, clothes washers and clothes dryers result in decreased electricity use and, therefore, a reduction of power plant emissions. The proposed efficiency standards will decrease air pollution by decreasing future energy demand. The greatest decreases in air pollution will be sulfur oxides, listed in equivalent weight of sulfur dioxide, or SO_2 . Some design options for dishwashers and clothes washers also reduce water consumption, resulting in lower in-house emissions from fuel-burning water heaters.

Although the quantity of raw materials used per appliance will remain relatively constant, in most scenarios increased initial cost is expected to slightly decrease the number of appliances sold, resulting in small decreases in raw materials used. This demand decrease is estimated by the LBL-REM in the TSD. The main effect of decreased appliance production is the SO_2 emitted in steel production. The decrease is small, however, in comparison to the SO_2 decreases from fuel burning avoided at power plants. The contribution from steel production is not included in the estimates for net SO_2 decreases resulting from design changes in these three products.

The design changes are described fully in Chapter 3 of the TSD. For dishwashers, the design changes analyzed are: reduced water use, improved motor efficiency, use of booster heater, and improved fill control. For clothes washers, the design changes are: eliminate warm/warm setting, eliminate warm rinse, horizontal axis design, thermostatic mixing valves, improved motor efficiency, and plastic tub. For clothes dryers, the design changes are: automatic termination, recycle exhaust, addition of insulation, use of microwave generators, and heat pump drying.

When the most efficient scenarios for each product are combined, the maximum decrease of SO₂ emissions is 1.4% of SO₂ in the U.S. power plant emissions for the year 2005. That represents a total of 246,000 tons of SO₂ abated for that year, 60% coming from the clothes dryers standard, 34% from the clothes washers standard, and 6% from the dishwashers standard.

Combining the most efficient scenarios of each product, the maximum decrease in NO₂ emissions is equal to 1.7% of the U.S. power plant emissions for the year 2005. This represents 164,000 tons of NO₂ abated for that year, 57% coming from the clothes dryers standard, 37% from the clothes washers standard and 6% from the dishwashers standard.

Another consequence of the candidate standards would be a reduction of carbon dioxide (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 gradually to raise the mean global temperature. Combining the most energy efficient scenarios for each of the three products results in a total reduction of CO₂ in 2005 of 15,100 thousand tons of carbon, which represents 0.87% 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, 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. (2)

Reduced hot water use will decrease the amount of gas or oil burned within some homes, thereby decreasing combustion effects 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 water heaters are normally vented to the outside, the projected changes in water heater use have little effect on indoor air quality.

D.2 METHODS OF ESTIMATING ENVIRONMENTAL IMPACTS

The greatest impacts of the proposed standards would result in less electricity generation. The main environmental effects of power plants on air and water quality result from emissions of sulfur oxides (SO_x), nitrogen oxides (NO_x), and carbon dioxide (CO₂). The symbols SO₂ and NO₂ represent all emissions of SO_x and NO_x expressed in the equivalent weights of SO₂ and NO₂, respectively. Carbon dioxide emissions are commonly expressed in tons of carbon. A second source of these pollutants is fuel-burning household water heaters. The proposed standards would also reduce these emissions. Since water heaters are normally vented to the outside, the sum of the power plant and in-house emissions are reported. Furthermore, reduced water consumption for dishwashers and clothes washers will result in a lower volume of waste water to be treated and in a reduced need for fresh water.

Table D.1. US CO₂, SO₂ and NO₂ Emissions

	CO ₂ US	SO ₂ US Power Plant	NO ₂ US Power Plant
Year	Emissions	Emissions	Emissions
	10 ⁶ Tons	10 ⁶ Tons	10 ⁶ Tons
1995	1600	17.25	8.25
2000	1630	18.00	8.79
2005	1750	17.50	9.62
2010	1820	17.10	10.24
2015	1900	16.13	10.65

The estimates of emissions of SO₂ and NO₂ are also expressed as a percentage of U.S. power plant emission for the year under consideration. The estimates of emissions of CO₂ are expressed as a percentage of U.S. total emission. Table D.1 summarizes the U.S. emissions for the three compounds. (3)

D.2.1 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 dishwashers, clothes washers and dryers, 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 for dishwashers, clothes washers and dryers includes the consideration of SO₂, NO₂ and CO₂ from in-home combustion of gas and oil.

Estimates of energy saved by reduced electricity generation are taken from the TSD. Primary energy saved from electricity generation at the margin is allocated among the categories of coal on the one hand, and gas plus oil on the other, by the ratios of 0.49 and 0.51, respectively, as estimated in supporting material for the Electric Utility Analysis, also in the TSD. This disaggregation into coal and oil-plus-gas is depicted in Figure D.1 for dishwashers. In order to capture the effects of cleaner-burning power plants in future years, emission rates for power plant fuel burning are calculated from projected emissions data and the projected quantities of the corresponding fuels used, as described in a report by Placet, are combined because, from an electric utility perspective, they are often interchangeable. (4) Linear interpolation and extrapolation are used to derive emissions rates for years not covered in the report. Tables D.2 and D.3 present the emission factors for NO₂ and SO₂ as they were used in the calculations.

Energy Savings due to Standards on Dishwashers

Level 1 Standards

Level 3 Standards

Figure 1. Electricity Savings Due to Standards on Dishwashers

Table D.2. Emission Factors for SO₂ and NO₂
For In-Home Combustion (10³ tons/Quad)

SO ₂ Oil	SO ₂ Gas	NO ₂ Oil	NO ₂ Gas
100	0.2	51	70

Table D.3. Emission Factors for SO₂ and NO₂
at Power Plant (10³ tons/Quad)

	SO ₂ Coal	SO ₂ Oil/Gas	NO ₂ Coal	NO ₂ Oil/Gas
1995	841	148	380	170
2000	768	143	367	171
2005	655	156	349	172
2010	577	148	340	148
2015	504	143	329	154

The values for reduction of SO₂ and NO₂ 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. Emissions factors for water heaters were only available for natural gas. (5) For oil-fired water heaters, the oil-fired space heater emission factors were used as default values. (6) All of these emission factors are consistent with theoretical emission factors from another source. (7)

D.2.2 Carbon Dioxide Emissions

Values for CO₂ abated are the sum of the CO₂ savings from coal-, gas-, and oil-fired power plants and, for dishwashers and clothes washers, the CO₂ emissions from in-home combustion of gas and oil. The energy saved from electricity generation is apportioned between coal and gas or oil as in the calculation of SO₂ and NO₂ emissions. In addition, gas and oil are disaggregated into relative shares of 0.71 and 0.29, respectively. These shares are the averages of the relative quantities of these fuels to be used for electricity generation in the years 1990 through 1995, as estimated by the North American Electric Reliability Council (NERC). (8). The energy values of the fuels saved are translated into tons of carbon using carbon/Btu values from the *Carbon Dioxide Review*. (9) The data for a more accurate method of estimating relative gas and oil shares concerning order of dispatch in the various NERC regions are not available. This disaggregation into fuel shares should therefore be taken only as a rough representation of power plant fuel choices on the margin. Table D.4 shows the emission factors for the different fuels, adjusted for generation, transmission and distribution losses.

Table D.4. CO₂ Emission Factors

10 ⁶ tons/Quad)		
Coal	Oil	Gas
27.8	20.2	15.9

D.3 RESULTS

D.3.1 DISHWASHERS

Decreases in the amounts of CO₂, SO₂ and NO₂ emitted at trial standards levels 1 through 5 are summarized in Tables D.5 through D.9. The columns "Abated from Gas (or Oil) Generation" include reductions in emissions from in-house water heaters.

D.3.1.1 Sulfur and Nitrogen Oxide Emissions

Sulfur dioxide emissions would be decreased by a cumulative total of 2.79 million tons between 1993 and 2015 in the level 5 scenario. In the year 1995, decreases in sulfur dioxide will represent about 0.23% of the SO₂ emissions estimated to come from power plants in that year. In the year 2005, decreases in SO₂ emissions will represent about 0.84% of the SO₂ emissions estimated to come from power plants in that year if standards are not established.

Level 5 design changes to clothes dryers would result in an estimated decrease in NO₂ emissions of 1.80 million tons between 1993 and 2015. NO₂ decreases would represent 0.26% and 0.97% of the NO₂ emissions estimated to come from power plants in the years 1995 and 2005, respectively.

D.3.1.2 Carbon Dioxide Emissions

The cumulative reduction in CO₂ emissions from level 5 design changes is 20,500 thousand tons of carbon. For the year 2005, the estimated CO₂ reduction is 1070 thousand tons of carbon or about 0.06% of estimated U.S. total CO₂ emissions for 2005.

Sulfur and Nitrogen Oxide Emissions

Sulfur dioxide emissions would be decreased by a cumulative total of 270,000 tons between 1993 and 2015 in the level 5 scenario. In the year 1995, decreases in sulfur dioxide represent roughly 0.02% of the SO₂ emissions estimated to come from power plants in that year. In the year 2005, decreases in SO₂ emissions represent about 0.09% of the SO₂ emissions estimated to come from power plants in that year if standards are not established. The savings peak around 2005 then level off as the existing stocks of dishwashers turns over.

Level 5 design changes to dishwashers would result in an estimated decrease in NO₂ emissions of 200,000 tons between 1993 and 2015. NO₂ decreases would represent 0.03% and 0.11% of the NO₂ emissions estimated to come from power plants in the years 1995 and 2005, respectively.

Table 5.
Reduction of Pollutants for Dishwashers - Level One

CO2 Reduction (in Thousand Tons of Carbon)

Year	Abated from Coal Generation	Abated from Gas Generation	Abated from Oil Generation	Net Change	% U.S.Planned Emissions
1995	48	51	12	111	0.01%
2000	131	134	33	298	0.02%
2005	199	197	50	446	0.03%
2010	235	228	57	520	0.03%
2015	250	239	61	549	0.03%

Cumulative CO2 reduction, 1993-2015 = 8,464 thousand tons of C

SO2 Reduction (in Tons)

Year	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change	% U.S. SO2 Power Plant Emissions
1995	1,445	274	1,719	0.01%
2000	3,621	736	4,357	0.02%
2005	4,693	1,193	5,886	0.03%
2010	4,874	1,329	6,203	0.04%
2015	4,530	1,361	5,891	0.04%

Cumulative SO2 reduction, 1993-2015 = 107,684 tons

NO2 Reduction (in Tons)

YEAR	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change (tons)	Percent of U.S. NO2 Power Plant Emissions
1995	654	442	1,096	0.01%
2000	1,729	1,187	2,916	0.03%
2005	2,499	1,783	4,282	0.04%
2010	2,875	1,872	4,748	0.05%
2015	2,956	2,027	4,983	0.05%

Cumulative NO2 reduction, 1993-2015 = 79,646 tons

Table 6.
Reduction of Pollutants for Dishwashers - Level Two

CO2 Reduction (in Thousand Tons of Carbon)

Year	Abated from Coal Generation	Abated from Gas Generation	Abated from Oil Generation	Net Change	% U.S.Planned Emissions
1995	55	54	14	122	0.01%
2000	150	144	37	331	0.02%
2005	228	209	56	493	0.03%
2010	269	244	65	578	0.03%
2015	287	254	69	610	0.03%

Cumulative CO2 reduction, 1993-2015 = 9,385 thousand tons of C

SO2 Reduction (in Tons)

Year	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change	% U.S. SO2 Power Plant Emissions
1995	1,652	311	1,963	0.01%
2000	4,149	841	4,989	0.03%
2005	5,368	1,360	6,728	0.04%
2010	5,583	1,518	7,100	0.04%
2015	5,198	1,557	6,755	0.04%

Cumulative SO2 reduction, 1993-2015 = 123,313 tons

NO2 Reduction (in Tons)

YEAR	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change (tons)	Percent of U.S. NO2 Power Plant Emissions
1995	747	485	1,232	0.01%
2000	1,981	1,316	3,297	0.04%
2005	2,859	1,966	4,825	0.05%
2010	3,293	2,068	5,361	0.05%
2015	3,392	2,239	5,631	0.05%

Cumulative NO2 reduction, 1993-2015 = 89,933 tons

Table 7.
Reduction of Pollutants for Dishwashers - Level Three

CO2 Reduction (in Thousand Tons of Carbon)

Year	Abated from Coal Generation	Abated from Gas Generation	Abated from Oil Generation	Net Change	% U.S.Planned Emissions
1995	81	89	20	189	0.01%
2000	224	238	55	517	0.03%
2005	340	349	84	774	0.04%
2010	404	407	101	911	0.05%
2015	430	429	106	965	0.05%

Cumulative CO2 reduction, 1993-2015 = 14,760 thousand tons of C

SO2 Reduction (in Tons)

Year	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change	% U.S. SO2 Power Plant Emissions
1995	2,437	454	2,891	0.02%
2000	6,185	1,254	7,439	0.04%
2005	8,003	2,034	10,037	0.06%
2010	8,388	2,296	10,684	0.06%
2015	7,797	2,351	10,149	0.06%

Cumulative SO2 reduction, 1993-2015 = 184,445 tons

NO2 Reduction (in Tons)

YEAR	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change (tons)	Percent of U.S. NO2 Power Plant Emissions
1995	1,102	755	1,857	0.02%
2000	2,954	2,064	5,017	0.06%
2005	4,263	3,100	7,362	0.08%
2010	4,948	3,292	8,240	0.08%
2015	5,088	3,572	8,660	0.08%

Cumulative NO2 reduction, 1993-2015 = 137,549 tons

Table 8.
Reduction of Pollutants for Dishwashers - Level Four

CO2 Reduction (in Thousand Tons of Carbon)

Year	Abated from Coal Generation	Abated from Gas Generation	Abated from Oil Generation	Net Change	% U.S.Planned Emissions
1995	105	98	25	228	0.01%
2000	292	263	70	626	0.04%
2005	442	386	107	935	0.05%
2010	526	452	125	1102	0.06%
2015	561	476	135	1172	0.06%

Cumulative CO2 reduction, 1993-2015 = 17,864 thousand tons of C

SO2 Reduction (in Tons)

Year	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change	% U.S. SO2 Power Plant Emissions
1995	3,180	590	3,770	0.02%
2000	8,071	1,626	9,697	0.05%
2005	10,414	2,630	13,044	0.07%
2010	10,910	2,957	13,867	0.08%
2015	10,174	3,048	13,222	0.08%

Cumulative SO2 reduction, 1993-2015 = 240,093 tons

NO2 Reduction (in Tons)

YEAR	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change (tons)	Percent of U.S. NO2 Power Plant Emissions
1995	1,438	904	2,343	0.03%
2000	3,854	2,484	6,338	0.07%
2005	5,547	3,728	9,275	0.10%
2010	6,436	3,930	10,366	0.10%
2015	6,639	4,288	10,927	0.10%

Cumulative NO2 reduction, 1993-2015 = 173,411 tons

Table 9.
Reduction of Pollutants for Dishwashers - Level Five

CO2 Reduction (in Thousand Tons of Carbon)

Year	Abated from Coal Generation	Abated from Gas Generation	Abated from Oil Generation	Net Change	% U.S.Planned Emissions
1995	120	114	28	262	0.02%
2000	333	303	81	717	0.04%
2005	505	445	121	1070	0.06%
2010	599	520	143	1262	0.07%
2015	640	548	154	1342	0.07%

Cumulative CO2 reduction, 1993-2015 = 20,463 thousand tons of C

SO2 Reduction (in Tons)

Year	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change	% U.S. SO2 Power Plant Emissions
1995	3,634	673	4,307	0.02%
2000	9,203	1,860	11,063	0.06%
2005	11,892	2,996	14,889	0.09%
2010	12,441	3,375	15,815	0.09%
2015	11,610	3,480	15,090	0.09%

Cumulative SO2 reduction, 1993-2015 = 273,997 tons

NO2 Reduction (in Tons)

YEAR	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change (tons)	Percent of U.S. NO2 Power Plant Emissions
1995	1,644	1,042	2,685	0.03%
2000	4,395	2,848	7,242	0.08%
2005	6,334	4,270	10,604	0.11%
2010	7,339	4,503	11,842	0.12%
2015	7,576	4,914	12,490	0.12%

Cumulative NO2 reduction, 1993-2015 = 198,236 tons

D.3.1.3 Water Savings

The new dishwasher standards would also save water. The following table summarizes the cumulative amount of water (in 10^9 gallons) consumed at each design level during the period 1993-2015.

	Baseline	Standard Level				
		1	2	3	4	5
Water Consumed	2972	2748	2746	2739	2733	2661
Water Saved		224	226	233	239	311

Standard level 5, has the highest water savings potential. Most of the savings comes from the first design option, reduced water use. Additional water savings comes from improved fill control. Levels 2, 3, and 4 have no direct potential for additional water reduction. The decreases shown in the table correspond to a lower number of appliances sold under these scenarios.

D.3.2 CLOTHES WASHERS

Decreases in the amounts of CO_2 , SO_2 and NO_2 emitted at trial standards levels 1 through 5 are summarized in Tables D.10 through D.14.

D.3.2.1 Sulfur and Nitrogen Oxide Emissions

Sulfur dioxide emissions would be decreased by a cumulative total of 1.57 million tons between 1993 and 2015 in the level 5 scenario. In the year 1995, decreases in sulfur dioxide will represent about 0.14% of the SO_2 emissions estimated to come from power plants in that year. In the year 2005, decreases in SO_2 emissions will represent about 0.48% of the SO_2 emissions estimated to come from power plants in that year if standards are not established.

Level 5 design changes to clothes washers would result in an estimated decrease in NO_2 emissions of 1.15 million tons between 1993 and 2015. NO_2 decreases would represent 0.18% and 0.63% of the NO_2 emissions estimated to come from power plants in the years 1995 and 2005, respectively.

D.3.2.2 Carbon Dioxide Emissions

The cumulative reduction in CO_2 emissions from level 5 design changes is 121.3 million tons of carbon. For the year 2005, the estimated CO_2 reduction is 6261 thousands tons of carbon or about 0.36% of estimated U.S. total CO_2 emissions in 2005.

D.3.2.3 Water Savings

The new clothes washer standards would also save water. The following table summarizes the cumulative amount of water (in 10^9 gallons) consumed at each design level during the period 1993-2015.

	Standard Level					
	Baseline	1	2	3	4	5
Water Consumed	23240	23234	23194	23015	15639	14901
Water Saved		6	46	225	7601	8339

Standard level 5 has the highest water savings potential. The savings shown for standard levels 4 and 5 result from the use of a horizontal axis clothes washer. This design requires much less water than the vertical axis design. Additionally, there is a (35%) decrease in shipments due to the much higher price of the product. None of the other designs directly decrease water use. Savings for standard levels 4 and 5 result from two factors: a reduction in per unit water consumption (31% reduction relative to vertical axis washer) and the increased price projected for horizontal-axis washers. The increased price in standard level 4 causes a 6.2% decrease in sales of clothes washers (7.9% for standard level 5).

D.3.3 CLOTHES DRYERS

Decreases in the amounts of CO_2 , SO_2 and NO_2 emitted at trial standards levels 1 through 5 are summarized in Tables D.15 through D.19.

D.3.3.1 Sulfur and Nitrogen Oxide Emissions

Sulfur dioxide emissions would be decreased by a cumulative total of 2.79 million tons between 1993 and 2015 in the level 5 scenario. In the year 1995, decreases in sulfur dioxide will represent about 0.23% of the SO_2 emissions estimated to come from power plants in that year. In the year 2005, decreases in SO_2 emissions will represent about 0.84% of the SO_2 emissions estimated to come from power plants in that year if standards are not established.

Level 5 design changes to clothes dryers would result in an estimated decrease in NO_2 emissions of 1.80 million tons between 1993 and 2015. NO_2 decreases would represent 0.26% and 0.97% of the NO_2 emissions estimated to come from power plants in the years 1995 and 2005, respectively.

D.3.3.2 Carbon Dioxide Emissions

The cumulative reduction in CO_2 emissions from level 5 design changes is 155.0 million tons of carbon. For the year 2015, the estimated CO_2 reduction is 7790 thousands tons of carbon or about 0.45% of estimated total U.S. CO_2 emissions.

D.4 EVALUATION OF ENVIRONMENTAL IMPACTS

D.4.1 Effects of Acid Precipitation

Sulfur dioxide is the major contributor to acid precipitation in the U.S. After a series of reactions with atmospheric gases and water, SO_2 forms sulfuric acid. More than half of the domestic SO_2 emitted as a result of human activities comes from coal burned in power plants. The next greatest contributor to acid precipitation is nitrogen dioxide. One-third of the domestic NO_2 emitted from human activities comes from electricity generating facilities (4).

Attaching values to incremental changes in acid precipitation is difficult. The effects of acid deposition on a given lake or forest depend on a variety of factors, including distance from pollutant source, buffering capacity, surrounding topography, rate of snow melt, soil or sediment type, etc. Acid precipitation can have negligible effects in buffered natural systems—those containing substances that take up or react with acids—until the buffering capacity is used up. Continued acid precipitation brings water and forest ecosystems closer to their buffering capacity limits, which can greatly affect living systems. Allowing a body of water to return to its natural state of alkalinity (buffering capacity) may require tens to thousands of years. In attempting to quantify the effects of acid precipitation, it is therefore important to consider cumulative effects that may not currently be obvious.

Some effects on humans resulting from adding acid to ecosystems are: decreases in fishing productivity, forest productivity, farming productivity, recreational opportunities, and the degradation of susceptible buildings and monuments.

The impacts of implementing any of the candidate standards on the abatement of SO_2 and NO_2 would be relatively small. (10) Implementing the most efficient standards for each product would produce a reduction, between 1993 and 2015, equal to 1.15% and 1.49% of cumulative U.S. power plant emissions of SO_2 and NO_2 , respectively. In the year of highest abatement, 2015, such standards would reduce U.S. SO_2 and NO_2 power plant emissions by 1.70% and 2.00%, respectively.

D.4.2 Perspectives on Changes in Carbon Dioxide Emissions

Atmospheric CO_2 is relatively transparent to incoming solar energy (short-wave radiation) but impedes outgoing solar energy, which is in the form of heat (long-wave radiation). The net result of elevated CO_2 concentrations is a trapping of heat near the earth's surface. This trapping of heat, referred to as the "greenhouse effect", raises the mean global temperature.

Because of human activity, the CO_2 concentrations in the atmosphere have increased from 290 parts per million (ppm) before the industrial era to about 345ppm in 1985. (11) Expected results of a global temperature change are: 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 followed by a rise in sea level. (12)

A doubling of the pre-industrial levels of CO₂ is projected to occur in the late part of the next century. (11) The process of controlling CO₂ concentrations is dependent on two factors: lead times involved in changing current trends in fossil-fuel use and lag times in environmental systems. If the goal were to keep CO₂ concentrations from exceeding 500 ppm, even a growth rate in fossil fuel use of 1.5% per year (compared to a growth rate of 2.3% in 1980) could not continue much beyond the end of this century. (9)

The impacts of implementing any of the candidate standards on the abatement of CO₂ would be relatively small. Implementing the most efficient standards for each product would reduce, between 1993 and 2015, 0.73% of cumulative U.S. emissions of CO₂. In the year of highest abatement, 2015, such standards would reduce U.S. CO₂ emissions by 1.10%.

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Table 10.
Reduction of Pollutants for Clothes Washers - Level One

CO2 Reduction (in Thousand Tons of Carbon)

Year	Abated from Coal Generation	Abated from Gas Generation	Abated from Oil Generation	Net Change	% U.S.Planned Emissions
1995	61	71	15	148	0.01%
2000	169	189	43	401	0.02%
2005	262	281	65	609	0.03%
2010	319	331	80	730	0.04%
2015	337	345	84	766	0.04%

Cumulative CO2 reduction, 1993-2015 = 11,683 thousand tons of C

SO2 Reduction (in Tons)

Year	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change	% U.S. SO2 Power Plant Emissions
1995	1,858	349	2,208	0.01%
2000	4,677	955	5,632	0.03%
2005	6,171	1,570	7,741	0.04%
2010	6,631	1,818	8,449	0.05%
2015	6,114	1,847	7,961	0.05%

Cumulative SO2 reduction, 1993-2015 = 143,396 tons

NO2 Reduction (in Tons)

YEAR	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change (tons)	Percent of U.S. NO2 Power Plant Emissions
1995	841	592	1,432	0.02%
2000	2,233	1,604	3,837	0.04%
2005	3,287	2,442	5,729	0.06%
2010	3,912	2,644	6,556	0.06%
2015	3,990	2,839	6,829	0.06%

Cumulative NO2 reduction, 1993-2015 = 107,810 tons

Table 11.
Reduction of Pollutants for Clothes Washers - Level Two

CO2 Reduction (in Thousand Tons of Carbon)

Year	Abated from Coal Generation	Abated from Gas Generation	Abated from Oil Generation	Net Change	% U.S.Planned Emissions
1995	79	80	19	179	0.01%
2000	218	213	54	485	0.03%
2005	334	317	81	732	0.04%
2010	408	373	99	881	0.05%
2015	431	389	105	925	0.05%

Cumulative CO2 reduction, 1993-2015 = 14,088 thousand tons of C

SO2 Reduction (in Tons)

Year	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change	% U.S. SO2 Power Plant Emissions
1995	2,395	447	2,842	0.02%
2000	6,035	1,224	7,258	0.04%
2005	7,875	1,991	9,866	0.06%
2010	8,473	2,308	10,781	0.06%
2015	7,822	2,348	10,170	0.06%

Cumulative SO2 reduction, 1993-2015 = 183,229 tons

NO2 Reduction (in Tons)

YEAR	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change (tons)	Percent of U.S. NO2 Power Plant Emissions
1995	1,083	711	1,795	0.02%
2000	2,882	1,931	4,812	0.05%
2005	4,194	2,927	7,121	0.07%
2010	4,999	3,155	8,154	0.08%
2015	5,105	3,400	8,504	0.08%

Cumulative NO2 reduction, 1993-2015 = 134,259 tons

Table 12.
Reduction of Pollutants for Clothes Washers - Level Three

CO2 Reduction (in Thousand Tons of Carbon)

Year	Abated from Coal Generation	Abated from Gas Generation	Abated from Oil Generation	Net Change	% U.S.Planned Emissions
1995	98	101	24	223	0.01%
2000	263	258	64	585	0.03%
2005	397	375	97	870	0.05%
2010	476	436	116	1029	0.06%
2015	500	450	121	1071	0.06%

Cumulative CO2 reduction, 1993-2015 = 16,634 thousand tons of C

SO2 Reduction (in Tons)

Year	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change	% U.S. SO2 Power Plant Emissions
1995	2,974	552	3,526	0.02%
2000	7,279	1,470	8,749	0.05%
2005	9,353	2,368	11,721	0.07%
2010	9,890	2,695	12,586	0.07%
2015	9,060	2,721	11,781	0.07%

Cumulative SO2 reduction, 1993-2015 = 216,794 tons

NO2 Reduction (in Tons)

YEAR	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change (tons)	Percent of U.S. NO2 Power Plant Emissions
1995	1,345	889	2,234	0.03%
2000	3,476	2,330	5,806	0.07%
2005	4,982	3,474	8,456	0.09%
2010	5,834	3,684	9,519	0.09%
2015	5,912	3,936	9,848	0.09%

Cumulative NO2 reduction, 1993-2015 = 158,625 tons

Table 13.
Reduction of Pollutants for Clothes Washers - Level Four

CO2 Reduction (in Thousand Tons of Carbon)

Year	Abated from Coal Generation	Abated from Gas Generation	Abated from Oil Generation	Net Change	% U.S.Planned Emissions
1995	637	648	160	1445	0.09%
2000	1769	1742	434	3944	0.23%
2005	2742	2608	669	6019	0.34%
2010	3371	3127	821	7319	0.40%
2015	3624	3332	880	7836	0.41%

Cumulative CO2 reduction, 1993-2015 = 116,491 thousand tons of C

SO2 Reduction (in Tons)

Year	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change	% U.S. SO2 Power Plant Emissions
1995	19,287	3,617	22,904	0.13%
2000	48,880	9,899	58,779	0.33%
2005	64,572	16,340	80,913	0.46%
2010	69,997	19,062	89,059	0.52%
2015	65,722	19,737	85,459	0.53%

Cumulative SO2 reduction, 1993-2015 = 1,506,603 tons

NO2 Reduction (in Tons)

YEAR	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change (tons)	Percent of U.S. NO2 Power Plant Emissions
1995	8,724	5,748	14,472	0.18%
2000	23,342	15,706	39,048	0.44%
2005	34,392	24,063	58,455	0.61%
2010	41,293	26,262	67,555	0.66%
2015	42,888	28,842	71,730	0.67%

Cumulative NO2 reduction, 1993-2015 = 1,107,326 tons

Table 14.
Reduction of Pollutants for Clothes Washers - Level Five

CO2 Reduction (in Thousand Tons of Carbon)

Year	Abated from Coal Generation	Abated from Gas Generation	Abated from Oil Generation	Net Change	% U.S.Planned Emissions
1995	662	672	165	1499	0.09%
2000	1841	1806	451	4099	0.24%
2005	2858	2707	696	6261	0.36%
2010	3520	3253	855	7628	0.42%
2015	3792	3473	921	8186	0.43%

Cumulative CO2 reduction, 1993-2015 = 121,289 thousand tons of C

SO2 Reduction (in Tons)

Year	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change	% U.S. SO2 Power Plant Emissions
1995	20,030	3,753	23,783	0.14%
2000	50,879	10,304	61,183	0.34%
2005	67,305	17,027	84,332	0.48%
2010	73,086	19,895	92,981	0.54%
2015	68,766	20,652	89,418	0.55%

Cumulative SO2 reduction, 1993-2015 = 1,570,919 tons

NO2 Reduction (in Tons)

YEAR	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change (tons)	Percent of U.S. NO2 Power Plant Emissions
1995	9,060	5,960	15,020	0.18%
2000	24,296	16,319	40,615	0.46%
2005	35,847	25,029	60,876	0.63%
2010	43,115	27,362	70,477	0.69%
2015	44,875	30,123	74,997	0.70%

Cumulative NO2 reduction, 1993-2015 = 1,153,968 tons

Table 15.
Reduction of Pollutants for Dryers - Level One

CO2 Reduction (in Thousand Tons of Carbon)

Year	Abated from Coal Generation	Abated from Gas Generation	Abated from Oil Generation	Net Change	% U.S.Planned Emissions
1995	85	44	19	147	0.01%
2000	246	126	54	425	0.03%
2005	392	202	86	679	0.04%
2010	510	244	112	866	0.05%
2015	584	264	128	976	0.05%

Cumulative CO2 reduction, 1993-2015 = 13,436 thousand tons of C

SO2 Reduction (in Tons)

Year	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change	% U.S. SO2 Power Plant Emissions
1995	2,561	466	3,027	0.02%
2000	6,789	1,341	8,130	0.05%
2005	9,225	2,283	11,508	0.07%
2010	10,599	2,821	13,419	0.08%
2015	10,595	3,108	13,703	0.08%

Cumulative SO2 reduction, 1993-2015 = 220,370 tons

NO2 Reduction (in Tons)

YEAR	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change (tons)	Percent of U.S. NO2 Power Plant Emissions
1995	1,158	573	1,731	0.02%
2000	3,242	1,662	4,904	0.06%
2005	4,913	2,672	7,585	0.08%
2010	6,252	2,946	9,199	0.09%
2015	6,914	3,424	10,338	0.10%

Cumulative NO2 reduction, 1993-2015 = 147,339 tons

Table 16.
Reduction of Pollutants for Dryers - Level Two

CO2 Reduction (in Thousand Tons of Carbon)

Year	Abated from Coal Generation	Abated from Gas Generation	Abated from Oil Generation	Net Change	% U.S.Planned Emissions
1995	115	60	25	199	0.01%
2000	329	172	72	573	0.03%
2005	521	272	114	908	0.05%
2010	674	335	148	1157	0.06%
2015	767	365	168	1300	0.07%

Cumulative CO2 reduction, 1993-2015 = 17,974 thousand tons of C

SO2 Reduction (in Tons)

Year	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change	% U.S. SO2 Power Plant Emissions
1995	3,469	632	4,101	0.02%
2000	9,090	1,796	10,885	0.06%
2005	12,278	3,039	15,317	0.09%
2010	13,999	3,726	17,725	0.10%
2015	13,912	4,082	17,993	0.11%

Cumulative SO2 reduction, 1993-2015 = 292,489 tons

NO2 Reduction (in Tons)

YEAR	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change (tons)	Percent of U.S. NO2 Power Plant Emissions
1995	1,569	778	2,347	0.03%
2000	4,341	2,241	6,582	0.07%
2005	6,539	3,573	10,112	0.11%
2010	8,259	3,949	12,208	0.12%
2015	9,078	4,577	13,655	0.13%

Cumulative NO2 reduction, 1993-2015 = 196,125 tons

Table 17.
Reduction of Pollutants for Dryers - Level Three

CO2 Reduction (in Thousand Tons of Carbon)

Year	Abated from Coal Generation	Abated from Gas Generation	Abated from Oil Generation	Net Change	% U.S.Planned Emissions
1995	222	116	49	387	0.02%
2000	618	328	135	1081	0.06%
2005	964	512	211	1686	0.10%
2010	1226	635	268	2129	0.12%
2015	1379	699	302	2380	0.13%

Cumulative CO2 reduction, 1993-2015 = 33,339 thousand tons of C

SO2 Reduction (in Tons)

Year	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change	% U.S. SO2 Power Plant Emissions
1995	6,732	1,226	7,958	0.05%
2000	17,085	3,375	20,461	0.11%
2005	22,692	5,617	28,308	0.16%
2010	25,448	6,773	32,222	0.19%
2015	25,001	7,336	32,337	0.20%

Cumulative SO2 reduction, 1993-2015 = 538,472 tons

NO2 Reduction (in Tons)

YEAR	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change (tons)	Percent of U.S. NO2 Power Plant Emissions
1995	3,045	1,512	4,557	0.06%
2000	8,159	4,231	12,389	0.14%
2005	12,086	6,638	18,724	0.19%
2010	15,013	7,290	22,302	0.22%
2015	16,315	8,416	24,731	0.23%

Cumulative NO2 reduction, 1993-2015 = 361,944 tons

Table 18.
Reduction of Pollutants for Dryers - Level Four

CO2 Reduction (in Thousand Tons of Carbon)

Year	Abated from Coal Generation	Abated from Gas Generation	Abated from Oil Generation	Net Change	% U.S.Planned Emissions
1995	565	237	124	925	0.06%
2000	1589	665	348	2602	0.15%
2005	2495	1043	546	4084	0.23%
2010	3175	1310	695	5180	0.28%
2015	3576	1465	783	5824	0.31%

Cumulative CO2 reduction, 1993-2015 = 80,901 thousand tons of C

SO2 Reduction (in Tons)

Year	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change	% U.S. SO2 Power Plant Emissions
1995	17,098	3,113	20,211	0.12%
2000	43,901	8,670	52,571	0.29%
2005	58,755	14,538	73,293	0.42%
2010	65,916	17,539	83,455	0.49%
2015	64,855	19,024	83,880	0.52%

Cumulative SO2 reduction, 1993-2015 = 1,390,914 tons

NO2 Reduction (in Tons)

YEAR	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change (tons)	Percent of U.S. NO2 Power Plant Emissions
1995	7,734	3,585	11,319	0.14%
2000	20,964	10,094	31,059	0.35%
2005	31,293	15,950	47,244	0.49%
2010	38,886	17,414	56,299	0.55%
2015	42,322	20,299	62,622	0.59%

Cumulative NO2 reduction, 1993-2015 = 912,192 tons

Table 19.
Reduction of Pollutants for Dryers - Level Five

CO2 Reduction (in Thousand Tons of Carbon)

Year	Abated from Coal Generation	Abated from Gas Generation	Abated from Oil Generation	Net Change	% U.S.Planned Emissions
1995	1092	381	239	1712	0.11%
2000	3139	1076	687	4902	0.29%
2005	5003	1693	1095	7790	0.45%
2010	6432	2149	1407	9988	0.55%
2015	7301	2428	1598	11327	0.60%

Cumulative CO2 reduction, 1993-2015 = 154,884 thousand tons of C

SO2 Reduction (in Tons)

Year	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change	% U.S. SO2 Power Plant Emissions
1995	33,039	6,014	39,053	0.23%
2000	86,746	17,128	103,875	0.58%
2005	117,799	29,142	146,941	0.84%
2010	133,532	35,523	169,055	0.99%
2015	132,409	38,831	171,240	1.06%

Cumulative SO2 reduction, 1993-2015 = 2,791,704 tons

NO2 Reduction (in Tons)

YEAR	Abated from Coal Generation	Abated from Gas/Oil Generation	Net Change (tons)	Percent of U.S. NO2 Power Plant Emissions
1995	14,944	6,591	21,535	0.26%
2000	41,424	18,896	60,320	0.69%
2005	62,741	30,229	92,970	0.97%
2010	78,774	33,054	111,828	1.09%
2015	86,406	38,966	125,372	1.18%

Cumulative NO2 reduction, 1993-2015 = 1,798,805 tons

REGULATORY IMPACT ANALYSIS

Energy Conservation Standards for Consumer Products

Covering: Dishwashers, Clothes Washers, and Clothes Dryers

**U.S. DEPARTMENT OF ENERGY
Conservation and Renewable Energy
Office of Building Technologies**

June 1990

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 which 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, 1990, to determine if the standards on dishwashers, clothes washers and clothes dryers should be amended. [Section 325(g) (4) (A) (i)] These three 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 which 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.

* "Major rule" means any regulation that is likely to result in:

- (1) An annual effect on the economy of \$100 million or more;
- (2) A major increase in costs or prices for consumers, individual industries, Federal, State, or local government agencies, or geographic regions; or
- (3) Significant adverse impacts on competition, employment, investment, productivity, innovation, or on the ability of the United States-based enterprises to compete with foreign-based enterprises in domestic or export markets.

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 LBL-REM could be determined. The LBL-REM was used to calculate the energy use and the net present value corresponding to each alternative. The key inputs to the LBL-REM 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;
- appliance stock data (purchase of new appliances or turnover rates for inventories).

An example of the input to the LBL-REM is shown in Table 2.1 for dishwashers, clothes washers, and clothes dryers. 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 LBL-REM 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 2.1. Summary of Key Inputs to the LBL-REM
To Simulate the Base Case**

**Escalation Rates for Energy Prices and Household Income
(Real Percent/Year)**

	Electricity	Natural Gas	Distillate Oil	Household Income
1987-1990	-0.01	-0.72	0.11	2.00
1990-2000	0.02	3.22	4.00	1.41
2000-2015	0.25	0.92	0.92	1.22

Market Discount Rates for Efficiency Choice (Percent)

Standard Dishwashers	99
Standard Water-heating Dishwashers	86
Compact Dishwashers	59
Standard Clothes Washers	216
Compact Clothes Washers	140
Standard Electric Clothes Dryers	80
Compact Electric Clothes Dryers (120V)	33
Compact Electric Clothes Dryers (240V)	36
Gas Clothes Dryers	26

Market Share Elasticities

	Electric Dryer	Gas Dryer	Dish-Washer	Clothes Washer
Operating expense	-0.11	-0.09	-0.08	-0.21
Income	0.50	0.20	0.50	-0.50
Equipment price (existing house)	0.15	0.15	0.15	0.15
Equipment price (new house)	0.15	0.15	0.15	0.15

Consumer Price vs. Energy Consumption
(Example: Standard Top-Loading Clothes Washer)

Design Option		Consumer Price (1987 \$)	kWh/Year
0	Baseline (5 Settings)	400	950
1	Eliminate Warm/Warm Setting	400	746
2	Eliminate Warm Rinse	400	674
3	2 + Improved Motor Efficiency	412	660
4	3 + Thermostat. Mix Valves	421	657
5	4 + Plastic Tub	442	653
6	2 + Horizontal Axis	571	262
7	6 + Plastic Tub	580	260
8	7 + Thermostat. Mix Valves	601	259

Source: U.S. DOE TSD.

The measures of impacts of each program are:

- *Residential Energy Use* (quadrillion Btu): Cumulative, 1993-2015 for dishwashers, clothes washers and clothes dryers. 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 1993-2015. 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 1987 using 7% real discount rate. Fuel expenses are calculated for the life of the appliance.

The additional columns presented in Table 2.2 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 program are compared alternative to the proposed standards. None of the alternatives show energy or economic savings comparable to the proposed program. The proposed approach appears to be less favorable than some of the other program alternatives in competition and reporting/compliance requirements.

Table 2-2. Expected Impacts of Program Alternatives

Impacts	Regulated Products		Net Present Value for Fuel and Equipment (in billions) (of 1987 \$)	Equity Impacts*	Legislative Authority	Major Barriers to Implementation/ Enforcement	Competition		Compliance and Reporting Requirements**
	Energy Use (QBtu)	Energy Savings (QBtu)							
Alternative									
No Action	34.18	0	None	None	***	None	None	None	None
Tax Credits (Consumers)	33.94	0.24	\$ 0.72	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)	34.19	-0.01	\$ 0.22	-	No	Enforcement problems likely	-	-	
Rebates (Consumers)	33.02	1.16	\$ 1.86	-	No	Potential difficulties in administration	-	-	
Prescriptive Standards	32.14	2.04	\$ 2.12	None	No	Restricts development of innovative technology	May reduce number of models and competition	Minimal reporting but extensive testing	
Voluntary Energy 5-yr delay	32.62	1.56	\$ 0.86	None	No	No assurance that participation will be widespread	None	None	
Efficiency 10-yr delay	33.28	0.90	\$ 0.53						
Enhanced Labeling and Consumer Education	34.18	0.01	\$ 0.01	None	Yes	None	None	Minimal	
Performance Standards	31.92	2.26	\$ 2.26	None	Yes	None	Not anti-competitive	Reasonable	

Key: None = 0 or not significant

QBtu = 10^{15} 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

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 2000 for the residential sector were developed by DOE in the Annual Report to Congress (1989). These prices after the year 2000 were extrapolated:

- In real terms, residential electricity prices are projected to decline at 0.5% per year until 1995, then increase at 0.5% per year until 2000. After 2000, electricity prices are projected to rise at 0.25% per year;
- Residential natural gas prices are projected to rise at 3.2% per year until 2000, then rise at 0.9% per year;
- Distillate oil prices are projected to rise at 4.0% per year until 2000, then rise at 0.9% 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 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 above, 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;
- There is a long lag before the effect of such educational activities is manifest in the marketplace.

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. The studies also indicated 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, on schedule.

2.2.4 Quantitative Description

The base case includes the following assumptions about factors likely to increase residential energy efficiency, which can be quantified in the LBL-REM:

- In real terms, residential electricity prices are projected to decline at 0.5% per year until 1995. It then increases at 0.5% per year until 2000 and at 0.25% per year thereafter. Residential natural gas prices are projected to rise at 3.2% per year until 2000, then at 0.9% per year thereafter. Distillate oil prices are projected to rise at 5.0% per year until 2000 and at 0.9% per year thereafter;
- The FTC labeling program for consumer products will continue;
- The U.S. Department of Energy'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 are based on operating expenses, as well as on equipment price. Appropriate weights for these are determined empirically.

The base case as quantified by the LBL-REM shows that cumulative residential energy demand for dishwashers, clothes washers, and clothes dryers from 1993 to 2015 will be 34.18 QBTu.* There are no energy savings associated with the base case.

The present value (in 1987 dollars, discounted at 7% real) of new appliances (dishwashers, clothes washers, and clothes dryers) purchased from 1993 to 2015 in the U.S. is projected to be \$140 billion, of which \$45 billion represents equipment prices and \$95 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 \$2,000 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 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.

* 1 QBTu = 10^{15} Btu of primary energy. Electricity consumption is converted to primary energy using the factor 1 kWh = 11,500 Btu.

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 LBL-REM results show energy savings of 0.24 QBTu for the consumer tax credit program alternative. The net present value (in 1987 dollars), discounted at 7% 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 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 product 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 Internal Revenue Service (IRS).

DOE would have to stipulate specific categories of investment subject to the credit. IRS would have principal responsibility for review of claims for the credit. Investigation of alleged violations would probably require joint action by DOE and 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 LBL-REM 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 LBL-REM.

Estimated energy consumption under this alternative increases by 0.01 QBtu between 1993 and 2015. The net present value (in 1987 dollars), discounted at 7% 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 baseline top-loading standard clothes washer consumes 950 kWh/year. If the price of a design consuming 657 kWh/y were \$21 higher than the baseline model, the consumer would receive a rebate of \$3.15. 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 1987 baseline model. The 15% reduction in incremental price is assumed to be paid by the Federal government. The LBL-REM model is run with the new price versus energy consumption curves, and results are compared with the base case.

The 15% rebate program alternative results in residential energy savings of 1.16 QBtu between 1993 and 2015. The net present value (in 1987 dollars), discounted at 7% 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 by assuming that prescriptive standards will achieve smaller efficiency improvements than performance standards in the same time frame.

Cumulative energy savings from 1993 to 2015 are estimated to be 2.04 QBtu. The net present value (in 1987 dollars), discounted at 7% 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 is total energy savings between 1993 and 2015 ranges from 1.56 QBtu (5-year delay) to 0.90 QBtu (10-year delay). The net present value (in 1987 dollars), discounted at 7% 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 noncompliance. An expanded program could more actively pursue the identification of noncomplying 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 tell consumers about the appearance of the consumer product labels and how to use 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 sales persons are 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 persons 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 by the user directly. For purposes of analysis, the reduction in discount rate (increase in acceptable payback period) is distributed equally among all consumers.

In general, any reasonable 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 residential energy savings from 1993 to 2015 are 0.01 QBTu and these savings have a net present value (in 1987 dollars, discounted at 7% 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, on a continuing basis, to modify 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 nonregulated 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 nonregulated 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 1987 dollars, discounted at 7% 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, the department 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 five, seven, and 10 percent. 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 (1987) *Annual energy outlook* of the Energy Information Administration. Appliance usage forecasts are taken from the results of the LBL-REM.

The differences in life-cycle costs between the base case and various levels of standards for dishwashers, clothes washers and clothes dryers are presented in Tables 6.11 - 6.13 of the TSD (1). These LCCs are calculated at a 7% discount rate; a higher rate, e.g., 15%, 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 3.1). 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, Section 3.

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 up to two trial standards levels that were slightly lower in efficiency and price and correspondingly higher in consumer life-cycle cost than the minimum.

Clothes washers and clothes dryers were analyzed at four trial standards levels and dishwashers were analyzed at three trial standards levels as described in the table below. In each case it is assumed that the standard level would be just stringent enough to induce manufactures to use all engineering design options up through the one listed. For a more complete description of these design options see Chapter 3 of the TSD.

**Correspondence Between
Standards Levels and Engineering Designs**

Standards Level	Dishwashers	Clothes Washers	Clothes Dryers
Level 0	Base Case	Base Case	Base Case
Level 1	Reduce Water Use	No Warm Rinse	Automatic Termination
Level 2	(1) + Improve Motor	(1) + Improved Motor	(1) + Insulation
Level 3	(1) + Booster Heater	(2) + Thermal Mix Valve	(2) + Recycle Exhaust
Level 4	(3) + Improve Motor	(1) + Horizontal Axis	(2) + Microwave
Level 5	(4) + Improve Fill Control	(4) + Thermal Mix Valve	(2) + Heat Pump

3.2 Impacts on Consumers

The major cost to consumers of stricter energy-efficiency standards is an increase the the purchase price of new products. As shown in Table 3.1, this increase ranges, depending on the standards level, from \$5 to \$29 for dishwashers, \$0 to \$166 for clothes washers, \$7 to \$264 for electric clothes dryers and \$6 to \$65 for gas clothes dryers.

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 3.2, which shows the present values of the life-cycle costs for appliances purchased between 1993 and 2015, discounted to 1987 at a 7% real rate. The changes in life-cycle cost range from an increase of \$11 to a decrease of \$11 for dishwashers, from a reduction of \$5 to \$53 for clothes washers, from a decrease of \$13 to \$45 for electric clothes dryers, and from an increase of \$11 to a decrease of three dollars for gas clothes dryers, depending on the standards level.

**Table 3.1 Projected Purchase Price of the Average New Appliance
(1987 Dollars)**

Appliance	Standards Level					
	Base	1	2	3	4	5
Dishwasher	320	325	327	331	337	349
Clothes Washer	432	432	438	454	567	598
Electric Clothes Dryer	304	311	322	370	465	568
Gas Clothes Dryer	347	353	364	412	412	412

Source: LBL-REM

Table 3.2 Present Value of Unit Life-Cycle Cost to Consumers
Discounted to 1987 at 7% Real (1987 Dollars)
(Average Over All New Units Purchased from 1993-2015)

Appliance	Base	Standards Level				
		1	2	3	4	5
Dishwasher	209	203	203	220	198	202
Clothes Washer	340	332	333	335	287	298
Electric Clothes Dryer	351	337	336	338	323	306
Gas Clothes Dryer	211	208	210	222	222	220

Source: LBL-REM

More details on the impacts of the proposed standards on consumers can be found in Chapters 5 and 6 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 appliance shipments, prices, revenues, net income and return on equity (ROE). These quantities are shown in Tables 3.3 to 3.5 for dishwasher, clothes washer, and clothes dryer manufacturers, 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 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.

Dishwasher and clothes washer manufacturers 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 7 of the TSD contains a detailed description of the impacts of standards on manufacturers.

Table 3.3 Dishwasher Output Table: Primary Scenario

**Output Table - Dishwasher
Scenario-Primary**

	1996 Base	Long Run				
		Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	0.70	0.70	0.70	0.69	0.69	0.68
Change (%)		0.28	0.15	-0.94	-0.79	2.43
S.E. (%)		1.14	1.23	2.35	2.17	2.88
Price (\$)	215.20	218.74	219.54	226.14	226.71	234.96
Change (%)		1.64	2.02	5.08	5.35	9.18
S.E. (%)		0.48	0.54	1.20	1.11	1.88
Revenue (in \$Mil)	150.48	153.32	153.74	156.64	157.28	160.30
Change (%)		1.88	2.17	4.09	4.51	6.53
S.E. (%)		1.02	1.10	2.12	2.01	2.78
Net Income (in \$Mil)	2.41	2.41	2.41	2.45	2.44	2.49
Change (%)		-0.24	-0.03	1.46	1.29	3.27
S.E. (%)		2.76	3.85	7.45	6.30	9.30
ROE (%)	6.77	6.65	6.59	6.5	6.51	6.74
Difference		-0.12	-0.18	-0.19	-0.26	0.03
S.E. (%)		0.19	0.24	0.48	0.41	0.58

3.4 Impacts on Electric Utilities

Appliance efficiency standards have three principal effects on electric utilities: 1) standards reduce revenues from electricity sales, 2) standards allow utilities to avoid fuel and other operating costs because less electricity has to be generated, and 3) standards may mean construction of new generating capacity is deferred. Changes in revenues depend on rate setting decisions by utilities and regulatory agencies, so it is difficult to estimate them accurately. Avoided costs and capacity savings are better defined than lost revenues, and they are treated in more detail in the utility analysis. A complete discussion of these calculations is presented in Chapter 8 of the TSD.

Calculating lost revenues depends on assumptions about economic fluctuations, regulatory behavior, voluntary consumer conservation, and existing tiered rate structures. Since rate structures differ widely among utilities and they are frequently changed by regulatory agencies, it would be nearly impossible to determine accurately lost revenues throughout the nation. 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 rate payers, 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.

Table 3.4 Clothes Washer Output Table: Primary Scenario

OUTPUT Table Scenario=Primary	CLOTHES WASHERS					
	Long Run					
	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	1.11	1.12	1.11	1.10	1.05	1.03
% change		0.38%	0.03%	-1.11%	-6.15%	-7.85%
S.E.		0.39%	0.47%	1.02%	4.97%	5.17%
Price	\$279.74	\$279.83	\$283.41	\$294.31	\$371.28	\$392.01
% change		0.03%	1.31%	5.21%	32.72%	40.14%
S.E.		0.58%	0.67%	1.32%	8.14%	8.44%
Revenue (in \$M)	311.67	312.94	315.86	324.27	388.20	402.46
% change		0.41%	1.34%	4.04%	24.56%	29.13%
S.E.		0.46%	0.58%	1.15%	7.38%	8.27%
Net Income (in \$M)	5.09	4.99	5.09	5.41	3.58	3.03
% change		-1.98%	-0.13%	6.11%	-29.79%	-40.43%
S.E.		4.21%	4.68%	8.01%	192.48%	214.52%
ROE	6.05%	5.86%	5.99%	6.31%	1.38%	1.17%
Difference		-0.19%	-0.06%	0.26%	-4.67%	-4.89%
S.E.		0.24%	0.25%	0.45%	2.41%	2.64%

Table 3.5 Clothes Dryer Table: Primary Scenario

OUTPUT Table Scenario=	CLOTHES DRYERS					
	Primary	Long Run				
	96 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (\$M)	0.80	0.81	0.80	0.76	0.73	0.70
% change		0.8%	-0.1%	-4.6%	-9.0%	-12.9%
S.E.		1.5%	2.1%	5.1%	7.9%	12.5%
Price	\$210.5	\$215.0	\$222.3	\$255.6	\$294.9	\$337.5
% change		2.1%	5.6%	21.5%	40.1%	60.4%
S.E.		0.4%	1.1%	4.0%	8.7%	12.4%
Revenue (\$M)	\$168.4	\$173.4	\$177.7	\$195.0	\$214.7	\$235.3
% change		3.0%	5.5%	15.8%	27.5%	39.7%
S.E.		1.5%	2.3%	6.1%	11.4%	18.5%
Net Income (\$M)	2.71	3.90	3.25	-1.10	-6.74	-13.40
% change		43.6%	19.8%	-140.5%	-348.5%	-593.6%
S.E.		64.2%	100.8%	268.8%	480.0%	887.2%
ROE	6.8%	9.6%	7.9%	-2.3%	-15.5%	-30.3%
Difference		2.8%	1.1%	-9.1%	-22.3%	-37.1%
S.E.		3.8%	5.7%	14.4%	30.9%	55.8%

Cumulative net revenue losses equal gross revenue losses minus avoided costs. Cumulative gross (net) revenue losses over the period 1993-2015 for electric clothes dryers range from \$4.1 to \$52 billion (net, \$1.6 to \$20 billion). For dishwashers, the cumulative gross (net) revenue losses range from \$1.6 billion to \$4.3 billion (net, \$0.4 to \$1.3 billion). Clothes washer gross (net) losses range from \$2.1 to \$24 billion (net, \$0.5 to \$6.1 billion). The gross losses are largely offset by avoided costs. Avoided costs have two components: avoided energy costs resulting from the reduction in electricity generated and avoided reliability (capacity) costs resulting from the reduction in peak loads. Avoided costs are calculated separately for standards on heating, cooling and baseload appliances because of the different seasonal and time-of-day effects of these appliance groups on energy and peak loads. The baseload avoided costs are used to value savings from standards on the three product types. Cumulative avoided costs between 1993 and 2015 for dishwashers range from \$1.2 billion to \$3.0 billion. For clothes washers they range from \$1.6 to \$18.0 billion, and for clothes dryers they range from \$2.5 to \$32.0 billion.

The reductions in peak load and the need for new capacity because of the proposed standards are summarized in Tables 8.1 through 8.6 in the TSD. Peak demand reductions from the standards for electric dryers range from 0.3 to 3.8 GW* in 2000, and from 0.7 to 8.9 GW in 2015.

Capacity savings for electric dryers range from 0.4 to 4.6 GW in 2000, and from 0.9 to 10.7 GW in 2015. Peak demand reductions from the standards for dishwashers range from 0.1 to 0.3 GW in 2000, and from 0.3 to 0.6 GW in 2015. Capacity savings for dishwashers range from 0.2 to 0.4 GW in 2000, and from 0.3 to 0.8 GW in 2015. Peak demand reductions from the standards for clothes washers range from 0.2 to 2.3 GW in 2000, and from 0.4 to 4.6 GW in 2015. Capacity savings for clothes washers range from 0.3 to 2.7 GW in 2000, and from 0.5 to 5.6 GW in 2015. These reductions in capacity will benefit electric utilities because they will have to raise less capital to construct new power plants.

3.5 National Impacts

3.5.1 Energy Savings

Standards for dishwashers, clothes washers, and clothes dryers result in energy savings for the period 1993-2015. Cumulative energy savings for dishwashers range from 0.42 Quads for standards level 1 to 0.99 Quads for standards level 5. Standards for clothes washers produce cumulative energy savings ranging from 0.57 Quads for standards level 1 to 5.92 Quads for standards level 5. Amended standards for clothes dryers produce cumulative energy savings that range from 0.61 Quads for standards level 1 to 6.39 Quads for standards level 5, and correspond to 4%-43% of base-case clothes dryer energy use. (See Tables 5.3, 5.10, and 5.17 of the TSD.)

* 1 GW = 1 Gigawatt = 1 million kilowatts = 1-1000 MW baseload power plant. 1 MW = 1 Megawatt = 1 thousand kilowatts

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 base case shipments between 1993 and 2015. The net present value to consumers is calculated using a discount rate of 7% and average electricity prices for these products. Table 3.6 displays the net present value of standards on dishwashers, clothes washers, and clothes dryers to consumers.

Table 3.6. Net Present Value to Consumers of Standards for Dishwashers, Clothes Washers, and Clothes Dryers
(Million 1987 Dollars Using Average Electricity Prices)
(Discounted to 1987 at 7% Real)

	Standards Level				
	1	2	3	4	5
Dishwashers	300	327	272	434	129
Clothes Washers	528	508	-135	1294	196
Electric Clothes Dryers	1212	1292	1009	1811	1285
Gas Clothes Dryers	51	9	-231	-284	-479

Source: LBL-REM

3.5.3 Environmental Impacts

The main environmental concern addressed here is emissions from fossil fuel-fired electricity generation. Each of the standards levels for dishwashers, clothes washers, and clothes dryers decreases electricity use and, therefore, reduces power plant emissions. The Environmental Assessment Document (4) contains a complete discussion of the environmental impacts of proposed standards for the three product types.

Power plant emissions include oxides of nitrogen and sulfur as well as carbon dioxide. 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. Carbon dioxide 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.

Stratospheric ozone absorbs ultraviolet radiation that would otherwise reach the Earth's surface. Increases in UV 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 dishwashers, clothes washers, and clothes dryers 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 1.40% of SO₂ in the U.S. power plant emissions for the year 2005. That represents a total of 246,000 tons of SO₂ abated for that year, 60% coming from the clothes dryers standard (level 5), 34% from the clothes washers standard (level 5) and 6% from the dishwashers standard (level 5). Combining the most efficient scenarios of each product, the maximum decrease in NO₂ emissions is equal to 1.70% of the U.S. power plant emissions for the year 2005. This represents 164,000 tons of NO₂ abated for that year, 57% coming from the clothes dryers standard level 5, 37% from the clothes washers standard level 5 and 6% from the dishwashers standard level 5.

Another consequence of the candidate standards would be a reduction of carbon dioxide (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 gradually to raise the mean global temperature. Combining the most energy efficient scenarios for each of the three products, results in a total reduction of CO₂ in 2005 of 15,100 thousand tons of carbon, which represents 0.87% 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, NO₂, and CO₂. Reduced hot water 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 four levels of standards for clothes washers and clothes dryers; and three levels for dishwashers. Based on the economic analysis, the most stringent energy-efficiency level that could be justified economically 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 United States;
- 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 provides 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 profitability of firms of various sizes. The results of these two models were used to compare the effects of alternative regulatory scenarios and are detailed in Chapters 5-7 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 incorporates these two impacts. The gross benefit to the consumer from appliance efficiency standards is the reduction in life-cycle cost (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 considered that had a higher life-cycle cost than the baseline unit, with the exception of gas clothes dryer. The benefits to consumers of proposed standards range from -\$1.5 for a standard gas clothes dryer to \$106 for a top loading standard clothes washer. The time over which the consumer recovers the higher initial price of the more efficient appliance ranges from 0 year for top loading standard clothes washers to 11 years for standard gas clothes dryers.

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 standard level 4 for dishwashers, standard level 1 for clothes washers, and standard level 2 for clothes dryers. Both the estimates of change in ROE and the uncertainty of these estimates expressed in standard deviations are presented in Table 4.1.

Table 4.1 Change in Profitability Due to Proposed Standards

	Dishwashers	Clothes Washers	Clothes Dryers
ROE Before	6.77%	6.05%	6.8%
ROE After	6.51%	5.86%	7.9%
Change in ROE	-0.26%	-0.19%	1.1%
SD of Change	0.41%	0.24%	5.7%

The most obvious and important trend in the structure of the appliance manufacturing 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. It is generally stimulated by the development of low profitability in certain firms (most often the small firms), which then become candidates for takeovers by larger, more profitable firms.

Since the analysis predicts little change in profitability in the dishwasher and clothes washer manufacturing industries, it is likely that the proposed standards would have no effect on the consolidation trend in the industry. The clothes dryer manufacturing industry shows increases in ROE greater than one percentage point at each standard level except, as noted above, at standard level 4, where a decrease in ROE is predicted, with a strong possibility that it will actually go negative. This decrease would force consolidation within the clothes dryer manufacturing industry before a return to normal profits.

Because one cannot reliably analyze the effects on individual firms that are caused by 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 will be reflected in increased or decreased profits. However, the demand for dishwashers, clothes washers, and clothes dryers will not disappear, and the industry 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. Because of this, 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 later when efficiency is considered.

4.5.3 The Multiplier

Counteracting the crowding-out effect is the multiplier 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. 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 the consumer is surprised by a price increase, he 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

There is still one effect on real GNP (but not employment) that is long lived and not subject to the rational expectations argument. Because standards make appliances more efficient, in the sense that they produce a given stream of utility for a lower present value, 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 dishwashing, clothes washing, and clothes drying for less, it will spend its money on something else, resulting in the same real consumption of dishwashing, clothes washing, and clothes drying and 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 by dishwasher, clothes washer, and clothes dryer manufacturers should be approximately \$170 million 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. These include the crowding-out effects. Using a conservative value of one would then suggest that GNP would be increased by approximately \$170 million per year shortly before standards take effect.

Another large increase will occur when standards are implemented because revenues in these industries are estimated to increase by approximately \$87 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 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 The 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 Table 2.2.

4.6.1 Tax Credits

Tax credits for consumers and for manufacturers were analyzed in sections 2.3 and 2.4 respectively. It is likely that tax credits for consumers will be a good incentive for them to purchase more efficient appliances. The impact will be smaller in proportion to the reduction in net present value (NPV) for fuel and equipment, as shown in Table 2.2. Thus, after implementation, the impacts should be 32% 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 2.2, the magnitude of these effects is indeed small.

4.6.2 Consumer Rebates

A program of consumer rebates is predicted to be a good 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 2.2. Thus, after implementation, the impacts should be 82% 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, with the exception of clothes washer which is already at standard level 1. For example, dishwashers will be at standard level 3 instead of level 4 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 2.2. Thus, after implementation the impacts should be 94% as large as those predicted for performance standards.

4.6.4 Voluntary Efficiency Targets

The macroeconomic impacts of voluntary targets will be much 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 23% and 38%, 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 38% (or 19%) of the performance standards impact. With a 10-year delay the impact would be at most one-fourth of 23% (or 11.5%) 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 2.2. After implementation, the impact is only 0.4% as large as that predicted for performance standards.

5. REFERENCES

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