TECHNICAL REPORT:
Analysis of Amended Energy Conservation Standards for Residential Refrigerator-Freezers

October 2005

U.S. Department of Energy
Assistant Secretary
Office of Energy Efficiency and Renewable Energy
Building Technologies Program
Appliances and Commercial Equipment Standards
Washington, DC 20585

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

The purpose of the analysis contained in this report is to provide the Department of Energy (DOE or the Department) with updated information to use in scheduling a new amended standards rulemaking for refrigerator-freezers in the 2006 appliance standards schedule setting process. Congress initially established conservation standards for refrigerators-freezers that became effective in 1990. The Department amended the standards with new standards that went into effect in 1993, followed by the current amended standards that went into effect in 2001. This analysis examines the technological and economic feasibility of new amended standards set at existing Energy Star levels for the two most popular product classes of refrigerators: top-mount refrigerator-freezers without through-the-door features and side-mount refrigerator-freezers with through-the-door features.

This technical report contains six chapters:

- Introduction
- Market and Technology Assessment
- Engineering Analysis
- Life-Cycle Cost and Payback Period Analysis
- National Impact Analysis
- Manufacturer Impact Analysis

The executive summary provides an overview of the analysis and results presented in Chapter 2 through Chapter 6 of this report.

Recently, Congress and the President passed and signed into law the Energy Policy Act of 2005 (EPACT 2005). This report summarizes some of the energy-efficient product provisions in EPACT 2005, but does not attempt to project the impact of these new provisions.

Market and Technology Assessment

Chapter 2 of this report presents the results of the market and technology assessment. Refrigerators, refrigerator-freezers, and freezers (including compact refrigerators) currently have an installed base in the United States of 183 million units and, collectively, have estimated national annual energy consumption in 2004 of over one quad. Two product classes represent a large proportion of total product shipments: (1) refrigerator-freezers with top-mount freezers and without through-the-door (TTD) service and (2) refrigerator-freezers with side-mount freezers and with TDD service. Consequently, the Department's assessment in this technical report focuses on these top-mount and side-mount refrigerator-freezers product classes.

Table ES-1 shows the unit energy consumption (UEC) of typically-sized top-mount and side-mount refrigerator-freezers. UECs are shown based on current DOE energy efficiency standards as well as those that correspond to existing voluntary efficiency programs, including Energy Star, the Federal Energy Management Program (FEMP), and the Consortium for Energy Efficiency (CEE).

Table ES-1. Maximum UEC Values for Refrigerator-Freezers with Different Specifications

Specification	UEC (kWh/year)	
	Top -Mount*	Side-Mount**
DOE Efficiency Standard	486	671
FEMP	460	620
Current Energy Star (15% decrease)	413	570
CEE Tier 1 (20% decrease)	389	537
CEE Tier 2 (25% decrease)	364	503
CEE Tier 3 (30% decrease)	340	469

* Auto defrost, no through-the-door features, 18.2 cu. ft. total volume, and 21.4 cu. ft. adjusted volume.
** Auto defrost, through-the-door features, 21.7 cu. ft. total volume, and 26.2 cu. ft. adjusted volume.

Technologies used to increase the energy efficiency of refrigerator-freezers include: high-efficiency compressors; variable-capacity compressors; high-efficiency evaporator and condenser fans; high-efficiency evaporator and condenser fan motors; eliminating thermal shorts; improved door face frame/gasket design; smart defrost technology; added cabinet insulation; lower-conductivity insulation; and vacuum panel insulation.

Engineering Analysis

Chapter 3 of this report presents the engineering analysis. The engineering analysis addressed the design changes and the added manufacturing cost of producing more efficient refrigerator-freezers. The Department analyzed two energy use reduction standard levels: (1) a product with 15 percent less annual energy consumption than a product meeting current energy conservation standards and (2) a product with 25 percent less annual energy consumption. Refrigerator-freezers with 15 percent less energy consumption correspond to products meeting current Energy Star requirements. Refrigerator-freezers with 25 percent less energy consumption correspond to products meeting potential future Energy Star levels, assuming new minimum efficiency standards are set at existing Energy Star levels.

The manufacturing cost assessment for the two improved efficiency levels primarily relies upon information from three sources:

- The Department's initial review of the DOE 1995 Technical Support Document (TSD);
- Industry-average data collected in May 2005, from refrigerator manufacturers by the Association of Home Appliance Manufacturers (AHAM) and provided to DOE; and
- Information provided by individual refrigerator manufacturers during interviews.

Analysis focused on top-mount and side-mount refrigerator-freezers, the two most popular product classes.

Achieving 15 percent energy use reduction can be done with many typical refrigerator-freezers through the use of higher-efficiency components. In order to achieve 25 percent energy use reduction, significant cabinet load reduction is generally required, leading to entire redesign of the units. While these changes are typical for many products, in many cases achieving the targeted energy use can be more difficult, thus leading to more drastic changes for 15 percent reduction and/or making redesign for 25 percent reduction impractical.

The manufacturing costs of achieving 15 percent and 25 percent energy use reductions for typical 18.2 cu. ft. top-mount and 21.7 cu. ft. side-mount refrigerator-freezers, as reported in the 1995 TSD (DOE 1995) and by the AHAM 2005 data collection effort, are summarized in Table ES-2. The average AHAM cost premiums are production volume-weighted averages.

Table ES-2. 1995 TSD and AHAM Manufacturing Cost Estimates

	Top-Mount *	Side-Mount **
15% Reduction (current Energy Star)	Note 1	
1995 TSD Cost Premium [$1992]	$26	$40
2005 AHAM Cost Premium (min.-avg.-max.)	$8 - $17 - $400	$5 - $27 - $95
25% Reduction		Note 2
1995 TSD Cost Premium [$1992]	No data	$53
2005 AHAM Cost Premium (min.-avg.-max.)	$18 - $54 - $141	$6 - $126 - $219

* Auto defrost, no through-the-door features, 18.2 cu. ft. total volume, and 21.4 cu. ft. adjusted volume
** Auto defrost, through-the-door features, 21.7 cu. ft. total volume, and 26.2 cu. ft. adjusted volume.
Note 1: The energy use of this design package for the TSD cost premium estimate is 2 percent above Energy Star.
Note 2: The energy use of this design package for the TSD cost premium is 1 percent above the energy use target.

Life-Cycle Cost and Payback Period Analysis

Chapter 4 presents the life-cycle cost (LCC) and payback period (PBP) analysis. The LCC and PBP analysis provide the Department with information on the economic impact of potential energy conservation standards on consumers for refrigerator-freezers with 15 percent less annual energy consumption than baseline products as well as refrigerator-freezers with 25 percent less annual energy consumption than the baseline product.

The Department calculated the LCC by adding the consumer retail price for the refrigerator-freezer, plus lifetime electricity costs (discounted and summed over the life of the refrigerator-freezer). The analysis compares the LCC of baseline products and more-efficient products. The Department also calculated the PBP, which is the ratio of the increase in consumer retail price due to a potential standard divided by the annual savings in electricity cost savings.

The Department calculated consumer retail prices based on the incremental manufacturing costs determined from the engineering analysis as well as from a regression analysis of price data from a large dataset of refrigerator-freezer sales data. Table ES-3 and Table ES-4 show the consumer retail prices of top-mount and side-mount refrigerator-freezers, respectively. Note that the retail prices based on the regression analysis were determined only at the 15 percent less energy use level.

Table ES-3. Consumer Retail Price and Retail Price Increases: Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service

	14-17 cu. ft.				18-20 cu. ft.				21-22 cu. ft.			
	Mfg. Cost-Based			Regress.-Based	Mfg. Cost-Based			Regress.-Based	Mfg. Cost-Based			Regress.-Based
	Min.	Avg.	Max.		Min.	Avg.	Max.		Min.	Avg.	Max.	
RETAIL PRICE (2005$)												
Baseline	$329				$386				$457			
15% less energy	$345	$367	$381	$356	$402	$420	$1186	$434	$477	$499	$531	$520
25% less energy	$457	$704	$1047	NA	$422	$494	$668	NA	$537	$613	$735	NA
RETAIL PRICE INCREASE (2005$)												
15% less energy	$16	$38	$52	$28	$16	$35	$800	$49	$20	$42	$74	$63
25% less energy	$128	$376	$718	NA	$36	$108	$282	NA	$80	$157	$278	NA

Table ES-4. Consumer Retail Price and Retail Price Increases: Refrigerator-Freezers with Side-Mount Freezer and with TTD Ice Service

	21-23 cu. ft.				24-26 cu. ft.				27-30 cu. ft.			
	Mfg. Cost-Based			Regress.-Based	Mfg. Cost-Based			Regress.-Based	Mfg. Cost-Based			Regress.-Based
	Min.	Avg.	Min.		Min.	Avg.	Max.		Min.	Avg.	Max.	
RETAIL PRICE (2005$)												
Baseline	$702				$789				$926			
15% less energy	$712	$756	$892	$750	$799	$824	$999	$855	$1008	$1110	$1136	$1014
25% less energy	$714	$955	$1140	NA	$849	$988	$1399	NA	Insufficient Data			NA
RETAIL PRICE INCREASE (2005$)												
15% less energy	$10	$54	$190	$47	$10	$35	$210	$66	$82	$184	$210	$88
25% less energy	$12	$253	$438	NA	$60	$199	$610	NA	Insufficient Data			NA

Table ES-5 and ES-6 show the LCCs, LCC savings, and PBPs for the 15 percent and 25 percent less energy use standard levels for top-mount and side-mount refrigerator-freezers. LCC presented in these tables is based on a discount rate of 6.7 percent and product lifetime of 19 years.

Table ES-5. LCC, LCC Savings, and Payback Periods: Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service

	14-17 cu. ft.				18-20 cu. ft.				21-22 cu. ft.			
	Mfg. Cost-Based			Regress.-Based	Mfg. Cost-Based			Regress.-Based	Mfg. Cost-Based			Regress-Based
	Min.	Avg.	Min.		Min.	Avg.	Max.		Min.	Avg.	Max.	
LCC (2005$)												
Baseline	$754				$849				$951			
15% less energy	$706	$729	$742	$718	$795	$814	$1579	$828	$897	$919	$951	$940
25% less energy	$776	$1023	$1366	NA	$769	$841	$1015	NA	$907	$984	$1105	NA
LCC SAVINGS (2005$)												
15% less energy	$48	$26	$12	$36	$53	$35	($731)	$21	$54	$32	$0	$11
25% less energy	($22)	($269)	($612)	NA	$80	$8	($166)	NA	$43	($33)	($155)	NA
PAYBACK PERIOD (years)												
15% less energy	2.9	6.9	9.5	5.0	2.7	5.8	133.9	8.1	3.1	6.7	11.6	10.0
25% less energy	14.0	41.1	78.5	NA	3.6	10.9	28.3	NA	7.5	14.7	26.2	NA

Table ES-6. LCC, LCC Savings, and Payback Periods: Refrigerator-Freezers with Side-Mount Freezer and with TTD Ice Service

	21-23 cu. ft.				24-26 cu. ft.				27-30 cu. ft.			
	Mfg. Cost-Based			Regress.-Based	Mfg. Cost-Based			Regress.-Based	Mfg. Cost-Based			Regress-Based
	Min.	Avg.	Min.		Min.	Avg.	Max.		Min.	Avg.	Max.	
LCC (2005$)												
Baseline	$1338				$1463				$1641			
15% less energy	$1253	$1296	$1433	$1290	$1372	$1398	$1572	$1428	$1615	$1717	$1743	$1621
25% less energy	$1191	$1432	$1617	NA	$1355	$1494	$1905	NA	Insufficient Data			NA
LCC SAVINGS (2005$)												
15% less energy	$85	$42	($95)	$48	$91	$66	($109)	$35	$25	($77)	($103)	$19
25% less energy	$147	($94)	($279)	NA	$109	($31)	($441)	NA	Insufficient Data			NA
PAYBACK PERIOD (years)												
15% less energy	1.2	6.6	23.2	5.8	1.1	4.1	24.1	7.6	8.9	19.9	22.8	9.6
25% less energy	0.9	18.5	32.1	NA	4.1	13.7	42.1	NA	Insufficient Data			NA

Reviewing the results of the LCC and PBP analysis, the Department identified the following:

- With certain exceptions, LCC savings are generally realized at the 15 percent less energy use standard level;
- With certain exceptions, LCC savings are not achieved at the 25 percent less energy use standard level;
- With certain exceptions, PBPs of less than half the lifetime of the product are realized at the 15 percent less energy use standard level; and
- With certain exceptions, PBPs exceed well over half the lifetime of the product at the 25 percent less energy use standard level.

National Impact Analysis

Chapter 5 presents the national impact analysis, consisting of the determination of national energy savings (NES) and national net present value (NPV) from an energy conservation (or efficiency) standard that would require refrigerator-freezers to use 15 percent less energy than current baseline models. For purposes of this analysis, the Department assumed the effective date of such a standard would be the year 2010. The Department calculated the NES and NPV based on an analysis period of 2010 through 2035.

In preparing this analysis, the Department found that the most critical input to the national impact analysis is the market share of future Energy Star products. For a new amended energy conservation standard set at current Energy Star levels (i.e., 15 less energy consumption), the Department assumed the future Energy Star level has 25 percent less energy consumption than current baseline products. Because it is difficult to forecast the market share of products once a new standard becomes effective, the Department analyzed the following two market share scenarios: (1) a No Future Energy Star scenario where 100 percent of the market is assumed to be at the new standard level (which is equivalent to the current Energy Star level), and (2) a

Current Energy Star scenario where market shares of current and future Energy Star are assumed to be equivalent to the market shares of current baseline and current Energy Star products.

Table ES-7 summarizes the NES and NPV results. Results of the national impact analysis are provided for the two standards case scenarios (No Future Energy Star and Current Energy Star), the two retail price estimates (manufacturing cost-based or regression analysis-based), and the two discount rates (three percent and seven percent real) considered for the national impact analysis. Because the Department could not use the regression analysis to generate prices for products with 25 percent less energy consumption, regression analysis-based retail prices are applicable only to the No Future Energy Star scenario.

For the No Future Energy Star standards case scenario, the NES due to standards for top-mount and side-mount refrigerator-freezers are 2.4 quads of primary energy (1.1 quads from top-mount refrigerator-freezers and 1.3 quads from side-mount refrigerator-freezers). For the Current Energy Star standards case scenario, the savings are 3.4 quads of primary energy (1.3 quads from top-mount refrigerator-freezers and 2.1 quads from side-mount refrigerator-freezers).

The NPV of standards depends on the scenario, the retail price estimate, and the discount rate. For a discount rate of three percent real, both standards case scenarios have a positive NPV. The NPV of the No Future Energy Star scenario is $10.1 billion with manufacturing cost-based retail prices and $8.0 billion with regression-based retail prices. The NPV of the Current Energy Star scenario is $3.3 billion. For a discount rate of seven percent real, the No Future Energy Star scenario still yields a positive NPV, $3.3 billion with manufacturing cost-based prices and $2.2 billion with regression-based prices, but the NPV under the Current Energy Star scenario becomes negative at -$1.2 billion.

The Current Energy Star scenario yields the greatest energy savings because of the assumed market share of future Energy Star products. But because of the significant retail price increase associated with future Energy Star products, the NPV of the Current Energy Star scenario is significantly lower than the NPV of the No Future Energy Star scenario.

Table ES-7. National Energy Savings and Net Present Value of Standards for Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service & with Side-Mount Freezer and with TTD Ice Service (2010–2035)

<table>
<tr><th rowspan="2">Standards Case Scenario</th><th rowspan="2">Retail Price Estimate</th><th rowspan="2">Discount Rate</th><th colspan="3">NES (quads)</th><th colspan="3">NPV (2005$)</th></tr>
<tr><th>Top-Mount</th><th>Side-Mount</th><th>Total</th><th>Top-Mount</th><th>Side-Mount</th><th>Total</th></tr>
<tr><td rowspan="2">No Future Energy Star</td><td>Mfg. Cost</td><td rowspan="3">3%</td><td rowspan="2">1.1</td><td rowspan="2">1.3</td><td rowspan="2">2.4</td><td>$4.0</td><td>$6.0</td><td>$10.1</td></tr>
<tr><td>Regress.</td><td>$3.3</td><td>$4.7</td><td>$8.0</td></tr>
<tr><td>Current Energy Star</td><td>Mfg. Cost</td><td>1.3</td><td>2.1</td><td>3.4</td><td>$2.4</td><td>$0.9</td><td>$3.3</td></tr>
<tr><td rowspan="2">No Future Energy Star</td><td>Mfg. Cost</td><td rowspan="3">7%</td><td rowspan="2">1.1</td><td rowspan="2">1.3</td><td rowspan="2">2.4</td><td>$1.3</td><td>$2.0</td><td>$3.3</td></tr>
<tr><td>Regress.</td><td>$0.9</td><td>$1.3</td><td>$2.2</td></tr>
<tr><td>Current Energy Star</td><td>Mfg. Cost</td><td>1.3</td><td>2.1</td><td>3.4</td><td>$0.2</td><td>($1.4)</td><td>($1.2)</td></tr>
</table>

Manufacturer Impact Analysis

Chapter 6 presents the Department's assessment of the impact of regulations on U.S. manufacturers of refrigerator-freezers. The Department carried out a preliminary evaluation of the impact of potential new regulations on manufacturer financial performance, domestic refrigerator-freezer manufacturing capacity and employment levels, and product utility and innovation. A primary focus was to identify the cumulative burden that industry faces from the overlapping effect of new or recent DOE standards and/or other regulatory action affecting the same product or industry. The primary sources of information for this evaluation were the structured interviews conducted in 2005 with manufacturers of refrigerator-freezers.

The Department received manufacturers' views on what they perceived to be the possible impact of potential new amended standards on their future profitability, especially in the context of the current standards, which have only been in effect since 2001. As stated by manufacturers, new amended energy efficiency standards have the potential to impact financial performance in several different ways. The capital investment needed to upgrade or redesign products and product platforms before they have reached the end of their useful life can require conversion costs that otherwise would not be expended, resulting in stranded investments. In addition, higher efficiency standards can result in higher per-unit costs that may deter some customers from buying higher-margin units with more features, thereby decreasing manufacturer profitability. Manufacturers stated that the prospect of product redesign as a result of new amended standards penalizes established manufacturers and alters the playing field for entry to the market by new competitors who do not carry debt burdens from recent investments in new product lines. In their view, this can decrease the relative barrier to entry of competitors into the market, which can increase market competition, reduce incumbent manufacturer profitability, and decrease U.S.-based production.

Typically, in the absence of new energy efficiency regulations, a refrigerator-freezer production line would have a life cycle of approximately 15 to 20 years. During that period, manufacturers would not make major product changes that altered the underlying platforms. Thus, a standard that took effect and resulted in a major product platform redesign before the end of the platform's life would cannibalize a portion of the earlier capital investments. Based on discussions with manufacturers, most have made significant capital investments to meet the DOE efficiency standard levels that took effect in 2001 and a new standard that required platform changes could strand assets before the end of their useful life. The 1995 TSD estimated the capital conversion costs for the 2001 standard at approximately 725 million dollars. Based on the interviews, this figure is low by a factor of two compared to the actual level of investment by the refrigerator-freezer industry in the years leading up to and immediately following the 2001 standards implementation. It must be noted, however, that not all of these costs can be attributed to efficiency standards since the platform changes entailed other product enhancements and cost reduction initiatives.

The Department asked manufacturers what level of conversion costs they anticipated if a new efficiency standard required a 15 percent reduction in unit energy consumption relative to the current standard. The level of expected conversion costs varied widely between manufacturers, depending on such factors as the energy performance of their current products, whether their current products could achieve the 15 percent reduction via component-level modifications or needed platform modifications, and the extent to which manufacturers expected to upgrade their platforms to allow for a future Energy Star level. At a minimum, a typical manufacturer would need to spend approximately 30 million dollars if no platform redesigns were needed. More likely, some manufacturers would need some level of platform redesign to reach a 15 percent improvement, particularly when the investments are taken in the context of future Energy Star levels. The potential for costs on the order of several hundred million dollars exists if even a single major manufacturer's product platforms undergo a full redesign. When asked to quantify the investments engendered by a 25 percent efficiency improvement, manufacturers referred to the investment level required by the 2001 standard and gave estimates totaling well over one billion dollars.

Several manufacturers indicated that a new standard level would cause existing pressures on margins and profitability to increase because only a limited portion of customers are willing to pay more for energy efficiency. Manufacturers believe that they could not pass on to customers all of the cost increases required to meet the standard, since historically, the appliance industry has not been able to recoup standards-induced capital costs in prices. Manufacturers reported that industry margins have actually decreased over time, since large manufacturers are willing to reduce margins to increase volumes because they need certain volumes to operate efficiently.

In addition, several manufacturers noted that a new energy-efficiency standard would facilitate the entry of foreign competitors into the U.S. market. Without a new standard, a new manufacturer would need to make large capital investments to build production capacity, -- investments that existing manufacturers would not need to make. In the case of a new standard, however, most manufacturers would need to carry out product platform redesigns for some of their products to meet the new standard. This would neutralize much of the cost advantage from existing infrastructure that current manufacturers have relative to new, foreign-based manufacturers.

Over the past several years, some refrigerator-freezer manufacturers have moved a portion of their production out of the U.S., primarily driven by concerns about profitability and the opportunity for lower labor costs. Mexico is the most common location for both U.S. and foreign manufacturers to establish new production capacity to serve the U.S. refrigerator-freezer market, as it offers low labor rates (relative to the U.S.) and proximity to the U.S. market. Based on information obtained through the interviews, the Department estimates that approximately 25 percent of all residential refrigerator-freezers sold in the U.S. are manufactured in Mexico and that this portion is likely to increase within a few years. Manufacturers indicated they anticipate that new standards would accelerate the trend to manufacture refrigerator-freezers outside of the country. Amended standards may alter the rate at which refrigerator-freezer production is moved to Mexico because if manufacturers need to make large capital investments to produce redesigned product platforms, they have strong financial incentives to invest in a location with lower labor costs. Given manufacturers' perceived need to offer Energy Star products, a new standard that requires a 15 percent reduction in unit energy may initiate the platform changes necessitating investment levels that would accelerate relocation of U.S. based manufacturing to Mexico

When assessing the benefits and burdens of a potential revision of product energy standard levels, the Department considers the regulatory burden that will impact the manufacturers of the product at or around the time the new standards would come into effect. Based on its own research and discussions with manufacturers, the Department identified several existing or pending regulations relevant to residential refrigerators, including:

- Existing energy efficiency standard for refrigerator-freezers
- Insulation blowing agent phase out
- Energy efficiency standards for other products made by the same manufacturers
- State energy efficiency standards
- International energy efficiency standards
- Waste disposal and recycling requirements

Complying with these regulations requires that corporations invest both human and capital resources.

In addition to the above, provisions of the recent Energy Policy Act of 2005 may have some impact on manufacturers; particularly the State consumer rebates for Energy Star products and the federal manufacturer tax incentives. This report summarizes some of the energy-efficient product provisions in EPACT 2005, but does not attempt to project the impact of these new provisions.

CHAPTER 1. INTRODUCTION

Congress initially established standards for residential refrigerators, refrigerator-freezers, and freezers that became effective in 1990. The Department amended the standards with new standards that went into effect in 1993, followed by the current amended standards that went into effect in 2001.

In April 2005, the Department granted a petition to conduct a rulemaking on new amended standards for residential refrigerator-freezers, based on meeting petition criteria set forth at 42 U.S.C. § 6295(n). However, the granting of the petition creates no presumption with respect to the Secretary's determination of whether a rulemaking meets the more rigorous criteria for amending standards. Since the Department's most recent analytical data is now ten years old (1995 TSD), the Department decided to conduct some limited new analyses to provide the Secretary of Energy with current information to use in scheduling a rulemaking on amending refrigerator-freezers standards in the 2006 appliance standards schedule setting process. This analysis examines the technological and economic feasibility of new standards set at existing Energy Star levels for the two most popular product classes of refrigerators: top-mount refrigerator-freezers without through-the-door features and side-mount refrigerator-freezers with through-the-door features. Because these two product classes account for over 85 percent of current product shipments, the Department confined its updated analysis to these two classes.

This report contains chapters on the following analyses:

- Market and Technology Assessment – Assesses the current U.S. market of refrigerator-freezers and identifies and assesses technologies for reducing refrigerator-freezer annual energy consumption. An assessment and status of the current test procedure is also provided.

- Engineering Analysis – Determines the incremental manufacturing cost of achieving annual energy use reductions of 15 and 25 percent relative to baseline products (i.e., products meeting current minimum efficiency standards). The 15 percent less energy use level corresponds to existing Energy Star levels. The 25 percent less energy use level corresponds to expected future Energy Star levels assuming new standards are set at existing Energy Star levels.

- Life-Cycle Cost and Payback Period Analysis – Determines the life-cycle cost (LCC) savings and payback periods of more efficient products based on: (1) incremental manufacturing costs determined from the Engineering Analysis and (2) incremental consumer retail prices from a regression analysis performed on a large data set of refrigerator sales data.

- National Impact Analysis – Determines the national energy savings (NES) and consumer net present value (NPV) of new standards set at existing Energy Star levels. Because the NES and NPV are dependent on the market share of expected future Energy Star products, results are provided for two market share scenarios; (1) no future Energy Star products and (2) future Energy Star product market shares equal to current market shares of existing Energy Star products.

- Manufacturer Impact Analysis – Determines the qualitative impacts to manufacturers of new standards set at existing Energy Star levels.

CHAPTER 2. MARKET AND TECHNOLOGY ASSESSMENT

2.1 MARKET ASSESSMENT

Refrigerators, refrigerator-freezers, and freezers are major household appliances designed for the refrigerated storage of food products. In 2001, 96 percent of households had at least one refrigerator or refrigerator-freezer. A refrigerator consists of a refrigerated cabinet designed for the refrigerated storage of food at temperatures above 0°C (32°F) and below 3.9°C (39°F), configured for general refrigerated food storage, and having a source of refrigeration requiring single phase, alternating current electric energy input only. A refrigerator may include a compartment for the storage of food at temperatures below 0°C (32°F), but does not provide a separate low temperature compartment designed for freezing and storage of food at temperatures below -13.3°C (8°F). A refrigerator-freezer is a cabinet which consists of at least one compartment designed for the refrigerated storage of food at temperatures above 0°C (32°F) and at least one other compartment designed for the freezing and storage of food at temperatures below -13.3°C (8°F). Top and bottom refrigerator-freezers have a horizontal partition between the freezer and refrigerator sections, with the freezer located above and below the refrigerator section, respectively. In contrast, side-mount units have a vertical partition between the freezer and refrigerator sections, with one on the right and the other on the left side of the unit. A freezer consists of a cabinet for the storage and freezing of foods at -17.8°C (0°F) or below. Compact refrigerators are defined by the DOE as having less than a 7.75 cubic foot capacity and 36 inches or less in height. The sales of compact refrigerators have increased appreciably in the last several years. While most seem to be sold to residential consumers, significant amounts are also prevalent in non-residential applications such as hotels, dormitories and offices.

Refrigerators and refrigerator-freezers account for about 83 percent of the annual energy consumption (AEC) and 78 percent of the installed base of residential refrigeration products (see Table 2-1).[1]

Table 2-1. Energy Consumption of Residential Refrigeration Equipment

Equipment Type	AEC (quads)	Installed Base (millions)
Refrigerators & Refrigerator-Freezers	0.86	142
Freezers	0.14	29
Compact Refrigerators	0.04	12

Source: DOE FY-2005 Priority Setting TSD.

Based on data from the Association of Home Appliance Manufacturers (AHAM), refrigerator-freezer shipments are much greater than refrigerator shipments.[2] In addition, top-mount and bottom-mount refrigerator-freezers historically have had approximately twice the sales volume of side-mount products (see Table 2-2).

Table 2-2. Residential Refrigerator and Refrigerator-Freezer Unit Shipment Data

Year	Refrigerator	Refrigerator-Freezers	
	One-Door	Top- and Bottom-Mount	Side-Mount
2004	164,614	6,925,454	3,832,129
2003	180,128	6,383,096	3,457,797
2002	61,880	6,488,361	3,194,103
2001	36,245	6,283,725	2,985,467
2000	33,151	6,297,553	2,885,902
1999	46,662	6,252,716	2,799,194
1998	75,535	6,077,185	2,624,970

Source: AHAM.

Consequently, the Department's assessment in this document focuses on top-mount and side-mount refrigerator-freezers because they account for a very large percentage of both installed base and AEC.

2.2 ENERGY PERFORMANCE

Refrigerator-freezer energy consumption is influenced by both mandatory and voluntary performance standards. Annual unit energy consumption (UEC) must fall below minimum levels established by DOE, which took effect in 2001.[3] The energy standards apply to refrigerators and refrigerator-freezers with a total refrigerated volume of less than 1104 liters (39 cubic feet) and to freezers with a total refrigerated volume of less than 850 liters (30 cubic feet). The mandated UEC's depend on product class and adjusted volume. Compact refrigerators and freezers represent separate product classes and have a volume less than 220 liters (7.75 cubic feet) *and* a height of 0.91 meters (36 inches) or less. The adjusted volume is equal to the fresh food internal volume plus 1.63 times the freezer internal volume. The energy standards are summarized in Table 2-3 below.

Table 2-3. Refrigerator, Refrigerator-Freezer, and Freezer Energy Efficiency Standards

Product class	Energy standards equations for maximum energy use (kWh/yr)	
	Effective January 1, 1993	Effective July 1, 2001
1. Refrigerators and Refrigerator-freezers with manual defrost	13.5AV+299 0.48av+299	8.82AV+248.4 0.31av+248.4
2. Refrigerator-Freezer—partial automatic defrost	10.4AV+398 0.37av+398	8.82AV+248.4 0.31av+248.4
3. Refrigerator-Freezers—automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators—automatic defrost	16.0AV+355 0.57av+355	9.80AV+276.0 0.35av+276.0
4. Refrigerator-Freezers—automatic defrost with side-mounted freezer without through-the-door ice service	11.8AV+501 0.42AV+501	4.91AV+507.5 0.17av+507.5
5. Refrigerator-Freezers—automatic defrost with bottom-mounted freezer without through-the-door ice service	16.5AV+367 0.58av+367	4.60AV+459.0 0.16av+459.0
6. Refrigerator-Freezers—automatic defrost with top-mounted freezer with through-the-door ice service	17.6AV+391 0.62av+391	10.20AV+356.0 0.36av+356.0
7. Refrigerator-Freezers—automatic defrost with side-mounted freezer with through-the-door ice service	16.3AV+527 0.58av+527	10.10AV+406.0 0.36av+406.0
8. Upright Freezers with Manual Defrost	10.3AV+264 0.36av+264	7.55AV+258.3 0.27av+258.3
9. Upright Freezers with Automatic Defrost	14.9AV+391 0.53av+391	12.43AV+326.1 0.44av+326.1
10. Chest Freezers and all other Freezers except Compact Freezers	11.0AV+160 0.39av+160	9.88AV+143.7 0.35av+143.7
11. Compact Refrigerators and Refrigerator-Freezers with Manual Defrost	13.5AV+299[a] 0.48av+299[a]	10.70AV+299.0 0.38av+299.0
12. Compact Refrigerator-Freezer—partial automatic defrost	10.4AV+398[a] 0.37av+398[a]	7.00AV+398.0 0.25av+398.0
13. Compact Refrigerator-Freezers—automatic defrost with top-mounted freezer and compact all-refrigerators—automatic defrost	16.0AV+355[a] 0.57av+355[a]	12.70AV+355.0 0.45av+355.0
14. Compact Refrigerator-Freezers—automatic defrost with side-mounted freezer	11.8AV+501[a] 0.42[illegible]+501[a]	7.60AV+501.0 0.27av+501.0
15. Compact Refrigerator-Freezers—automatic defrost with bottom-mounted freezer	16.5AV+367[a] 0.58av+367[a]	13.10AV+367.0 0.46av+367.0
16. Compact Upright Freezers with Manual Defrost	10.3AV+264[a] 0.36av+264[a]	9.78AV+250.8 0.35av+250.8
17. Compact Upright Freezers with Automatic Defrost	14.9AV+391[a] 0.53av+391[a]	11.40AV+391.0 0.40av+391.0
18. Compact Chest Freezers	11.0AV+160[a] 0.39av+160[a]	10.45AV+152.0 0.37av+152.0

AV: Adjusted Volume in cubic feet
av: Adjusted Volume in liters

Much of the technical discussion in this report focuses on top-mount refrigerator-freezers without through-the-door features and side-mount refrigerator-freezers with through-the-door features, since these two product classes make up a very large proportion of the overall market. Furthermore, the Department focused on a top-mount with 18.2 total internal volume (21.4 cu. ft. adjusted volume) and a side-mount with 21.7 total internal volume (26.2 cu. ft. adjusted volume). These refrigerator-freezer sizes are typical for their product classes and were selected for detailed analysis as part of the 1995 TSD.

In addition to mandatory standards, there are voluntary efficiency programs, including Energy Star, the Federal Energy Management Program (FEMP), and the Consortium for Energy Efficiency (CEE). Table 2-4 presents maximum unit energy consumption (UEC) values for the DOE standard and the three aforementioned voluntary standards for a top- mount refrigerator-freezer with auto defrost and no through-the-door features and a side-mount refrigerator freezer with through-the-door features, with 21.4 cu. ft. and 26.2 cu. ft. adjusted volumes, respectively. Energy Star specifies annual energy use reduction targets of 15 percent for standard size refrigerator-freezers. The Consortium for Energy Efficiency (CEE) identifies three tier levels specifying annual energy use reduction targets of 20, 25, and 30 percent relative to current minimum efficiency standards (for Tiers 1, 2, and 3). As of July 2005, the Energy Star refrigerators database included 79 refrigerator-freezer models with an adjusted volume of at least 18 cu. ft. that met the CEE Tier 1 performance level and four models that met the CEE Tier 2 performance level.[4]

Table 2-4. Maximum UEC Values for Refrigerator-Freezers with Different Specifications

	UEC (kWh/year)		
Specification	**Top & Bottom***	**Side-Mount****	**Specific Source**
DOE Efficiency Standard	486	671	Energy Star (2004)[5]
FEMP	460	620	FEMP (2005)[6]
Current Energy Star (15% decrease)	413	570	Energy Star (2004)[6]
CEE Tier 1 (20% decrease)	389	537	CEE (2004)[7]
CEE Tier 2 (25% decrease)	364	503	
CEE Tier 3 (30% decrease)	340	469	

* Auto defrost, no through-the-door features, 18.2 cu. ft. total volume, and 21.4 cu. ft. adjusted volume.
** Auto defrost, through-the-door features, 21.7 cu. ft. total volume, and 26.2 cu. ft. adjusted volume.
Source: DOE FY-2005 Priority Setting TSD.

DOE and Energy Star levels have the greatest impact on products sold, i.e., the DOE standards apply to all products sold and Energy Star units account for approximately 20 percent and 50 percent of top- & bottom-mount and side-mount refrigerator-freezer units sold, respectively.[2]

2.3 DESIGN OPTIONS TO IMPROVE EFFICIENCY

Refrigerator-freezer energy efficiency can be increased in several ways, including (but not limited to) using the design options listed below. To varying degrees, existing products incorporate one or more of these approaches to meet existing DOE mandatory and other voluntary (e.g., Energy Star) efficiency levels.

- Higher-efficiency compressors. Energy Efficiency Ratios (EER's) of compressors used in standard-size refrigerator-freezers can range from about 5 to about 6.1 Btu/hr-W at standard rating conditions. Higher-efficiency compressors use less energy but are also more expensive.

- Variable-capacity compressors. Variable-speed compressors operate at a range of speeds in order to allow capacity modulation. They generally use permanent magnet motors and require power electronics to vary the speed. The additional power electronic hardware makes them more expensive. Furthermore, implementation cost can be more expensive, because control of variable-speed compressors requires a more sophisticated control approach, which can require use of electronic control. Energy savings are possible with variable-speed compressors because they operate with reduced mass flow over longer time periods to deliver the same amount of refrigeration as a single-speed unit. The reduced mass flow allows the refrigerant temperatures in the evaporator and condenser to more closely approach the air temperatures, thus reducing temperature lift.

- More efficient evaporator and condenser fans. Advanced-design fan blades can reduce losses associated with movement of air.

- More efficient evaporator and condenser fan motors. Shaded-pole motors were used traditionally to power evaporator and condenser fans. These motors were inexpensive but inefficient. Brushless-DC motors with AC-power input have been commercialized. These motors are significantly more efficient.

- Eliminating thermal shorts. Unintended heat leak paths through the walls and door panels of refrigerator-freezers can exist where there are wall penetrations, liner transitions, etc. Careful design to eliminate and/or reduce heat leak paths can significantly reduce total refrigeration load.

- Improved door face frame/gasket design. The potential for high heat leak at the doorframe is due to the transition from internal to external liners in this area, and the potential for gaps between the doors and cabinet to allow infiltration. The added heat leak in this area generally cannot be completely avoided, leading to the almost universal use of anti-sweat heating (provided by electric heaters and/or refrigerant lines carrying hot gas or liquid refrigerant) to keep externally exposed refrigerator surfaces from condensing ambient moisture in humid climates. Careful design of this area can significantly reduce load and energy use.

- Using smart defrost technology, such as adaptive defrost control (ADC) to minimize the amount of defrost that is needed. One adaptive defrost control approach is to adjust the defrost time interval based on the time required for the defrost heater to warm the evaporator up to the defrost termination temperature. A quick warm-up time indicates a small frost layer (i.e. due to low exterior humidity and/or infrequent door openings), which indicates that a longer time interval is possible.

- Adding more cabinet insulation to reduce thermal losses, i.e. increasing thickness of walls or doors.

- Using a blowing agent, which provides a lower-conductivity insulation. Manufacturers have had to move away from CFC- and HCFC-based blowing agents. A range of blowing agents is in use today. The different options provide varying insulation thermal conductivity. Switching to a more efficient blowing agent could reduce cabinet load but may be more costly.

- Vacuum panel insulation. Vacuum panels have been commercially available for a number of years but have not been adopted in any significant quantity for domestic refrigeration products due to their relatively high cost. However, this technology can significantly reduce refrigeration load without increasing wall thickness.

2.4 TEST PROCEDURE STATUS

Standard-size refrigerators, refrigerator-freezers, freezers, and compact refrigerators are all covered under the same DOE test procedure. They are tested at an ambient temperature of 90°F while internal volume temperatures are kept within specified temperature conditions. DOE has recently taken action on some issues regarding the test procedure. Also, there have been recent actions to improve AHAM's test standard. The National Institute of Standards and Technology (NIST) has investigated the possibility of harmonizing the U.S. test procedure with international test standards. These issues are described in more detail below.

2.4.1 Credit for a more efficient defrost system

DOE issued a direct final rule, which became effective in May 2003, amending the calculation of the test time period for "long-time" automatic defrost units.[8] This change gives credit for a control capable of initiating defrost during a compressor off-cycle, thereby saving energy by taking advantage of the natural warming of the evaporator during the compressor off cycle. This revision has no effect on the testing of refrigerators and refrigerator-freezers that do not employ a long-time automatic defrost system.

2.4.2 Change in electric refrigerator definition to exclude wine coolers

Several manufacturers of wine coolers requested exemptions from the refrigerator energy efficiency standards. Some wine coolers are made with glass front doors, which make them less energy efficient than standard refrigerators. As a result, the Department amended the definition of "electric refrigerator", effective December 19, 2001, to include a maximum temperature of the fresh food storage compartment, and to exclude certain appliances whose physical configuration makes them unsuitable for general storage of perishable foods. The purpose of the revised electric refrigerator definition was to exclude wine coolers from the energy efficiency regulations.[9] This rule may also affect other compact refrigerators designed to store and cool beverages other than wine. For example, since the time of the test procedure revision, a new product has entered the market that is both a compact refrigerator and wine cooler whose performance cannot be rated by the existing test procedure.

2.4.3 Repeatability issues for testing compact refrigerators

Because of inconsistencies in test results for compact refrigerators, the National Institute of Standards and Technology (NIST) investigated repeatability issues and published a report entitled "Repeatability of Energy Consumption Test Results for Compact Refrigerators".[10] In addition, NIST participated in a task force formed by the Association of Home Appliance Manufacturers (AHAM) to revise their AHAM HRF-1 test procedure. The latest version of AHAM's test procedure is now AHAM HRF-1, 2003. But the existing DOE test procedure still references an older version of the AHAM test procedure, AHAM HRF-1, 1979. DOE may need to amend the test procedure to reference the most recent version of AHAM HRF-1.

2.4.4 Harmonizing with international standards

NIST has done comparisons between ISO's international test standards and the North American (i.e., the DOE) test standard. The two test procedures are similar but not identical. Differences include the ambient temperature at which the refrigerators are tested and the ISO specified test load. There is some interest in harmonizing and unifying the two test procedures by manufacturers interested in international trade. Recently, the United States, Canada, and Mexico have harmonized their test procedures.

REFERENCES

1 U.S. Department of Energy, *FY 2005 Preliminary Priority-Setting Summary Report - Appendix A: FY 2005 Technical Support Document (TSD)*, 2005. Washington, DC. Available at: http://www.eere.energy.gov/buildings/appliance_standards/pdfs/fy05_priority_setting_app_a.pdf.

2 Association of Home Appliance Manufacturers, *Summary Data Tables: Refrigerator-Freezer Data Collection for Cost/Efficiency Information for DOE Petition*, 2005. Information provided by the Association of Home Appliance Manufacturers (AHAM) to the U.S. Department of Energy, May 13, 2005.

3 U.S. Department of Energy-Office of Energy Efficiency and Renewable Energy, Energy Conservation Program for Consumer Products: Energy Conservation Standards for Refrigerators, Refrigerator-Freezers and Freezers; Final Rule. *Federal Register*, 1997. 62(81): pp. 23102-23116.

4 Energy Star, *ENERGY STAR Refrigerators & Freezers Product List*, July 5, 2005. Available at: http://www.energystar.gov/index.cfm?c=refrig.pr_refrigerators.

5 Energy Star, *Refrigerators & Freezers Key Product Criteria*, 2004. Energy Star Product Information. Available at: http://www.energystar.gov/index.cfm?c=refrig.pr_crit_refrigerators.

6 Federal Energy Management Program, *How to Buy an Energy-Efficient Residential Refrigerator,* 2004. Washington, DC. September. Available at: http://www.eere.energy.gov/femp/pdfs/refrig.pdf.

7 Consortium for Energy Efficiency, *High-Efficiency Specifications for Dishwashers and Refrigerators, Consortium for Energy Efficiency (CEE) Super-Efficient Home Appliances Initiative*, 2004. Boston, MA. Available at: http://www.cee1.org/resid/seha/dishw/dishwash-refrig_specs.pdf.

8 U.S. Department of Energy-Office of Energy Efficiency and Renewable Energy, Energy Conservation Program for Consumer Products: Test Procedure for Refrigerators and Refrigerator-Freezers; Direct Final Rule. *Federal Register*, 2003, 68(45): pp. 10957-10961.

9 U.S. Department of Energy-Office of Energy Efficiency and Renewable Energy, Energy Conservation Program for Consumer Products: Amendment to the Definition of Electric Refrigerator; Final Rule. *Federal Register*, 2001, 66(223): pp. 57845-57848.

10 National Institute of Standards and Technology, 2000, *Repeatability of Energy Consumption Test Results for Compact Refrigerators*, September 2000. Gaithersburg, MD. Report No. NISTIR-6560. Available at: http://fire.nist.gov/bfrlpubs/build00/art055.html.

CHAPTER 3. ENGINEERING ANALYSIS

In order to estimate the design and cost impacts of different potential standard levels, the Department used three information sources:

- The Department's 1995 Technical Support Document (TSD), prepared as part of the 2001 Energy-Efficiency Standard.[1]
- Cost impact data collected by the Association of Home Appliance Manufacturers (AHAM) from its member companies in 2005 and consolidated for DOE use and review.[2]
- Information regarding required design changes provided by manufacturers during interviews.

3.1 REVIEW OF 1995 TSD

The Department re-evaluated the analysis presented in its 1995 Technical Support Document (TSD) for refrigerator-freezers (see Table 3-1). Note that the TSD analysis started with a baseline energy use, which is 16 percent below the 1993 Standards for the side-mount product class, while the top-mount baseline was equivalent to the 1993 Standard. Table 3-1 summarizes the efficiency levels analyzed in the 1995 TSD in relation to 1993 and 2001 Energy Standards and the potential new standard levels.

Table 3-1. TSD Energy Use Calculations

	UEC (kWh/year)	
Case	**Top-Mount***	**Side-Mount****
1993 Energy Efficiency Standard	*697*	*954*
2001 Energy Efficiency Standard	*486*	*671*
15% Reduction (Current Energy Star)	*413*	*570*
25% Reduction	*365*	*503*
1995 TSD Analysis Baseline	**701**	**800**
1995 TSD Analysis Minimum	**422**	**508**

* Auto defrost, no through-the-door features, 18.2 cu. ft. total volume, and 21.4 cu. ft. adjusted volume.
** Auto defrost, through-the-door features, 21.7 cu. ft. total volume, and 26.2 cu. ft. adjusted volume.
Source: DOE 1995 TSD.

3.1.1 Top-Mount Refrigerators

The 1995 analysis identified two design paths for the top-mount product class to achieve the minimum 422 kWh energy use (two percent higher than current Energy Star). Both paths included:

- Higher-efficiency compressor (increase from 4.68 to 5.45 EER)
- Higher-efficiency evaporator fan
- Higher-efficiency evaporator and condenser fan motors (motor input wattage reduction from 9.1W for the evaporator fan and 12W for the condenser fan to 4.5W for each)
- Improved gaskets
- Increased condenser and evaporator areas, and
- Adaptive defrost control (ADC).

In addition, the first design path incorporated 2.54cm (one-inch) wall and door insulation thickness increases, while the second incorporated vacuum panels. Baseline insulation thicknesses were 3.8 cm (1.5 inch) for the doors, 5.5 cm (2.2 inch) average for the freezer walls, and 4.3 cm (1.7 inch) average for the fresh food walls. The vacuum panel option assumed that half of the total wall and door surfaces would be covered with 1-inch thick vacuum panels. The TSD does not provide detail regarding all of the design options listed. For example, the percent increase in condenser and evaporator areas was not specified.

Note that the design option paths described in this section would be applied to units achieving compliance with the 1993 Energy Standard. Hence, today's refrigerator-freezers would already incorporate some of these options.

While the minimum UEC for the TSD top-mount analysis is not down to the 413 kWh/year level of the current Energy Star, it is nearly down to this level. Compressors with EER's up to about 6.1 Btu/W-hr are available today, so the same combination of design options using today's best compressors would likely meet the Energy Star level. One of the design paths achieving the 422 kWh/year level does not require vacuum panels, suggesting that this level of energy use can be achieved with readily available components at reasonable cost. In practice, about 20 percent of the top- and bottom-mount units sold today meet the Energy Star performance level[2], which reinforces the observation that there exist ways to achieve this efficiency level at reasonable cost.

The TSD analysis does not provide any indication of which design options would be required to achieve energy use 25 percent below the 2001 Standard for top-mount refrigerators.

3.1.2 Side-Mount Refrigerators

Three of the TSD analysis design paths for the side-mount product class achieved the current Energy Star performance level. All of these incorporated:

- Higher-efficiency compressor (increase from 5.18 to 5.6 EER)
- Higher-efficiency evaporator fan

- Higher-efficiency evaporator and condenser fan motors (motor input wattage reduction from 8.0W for the evaporator fan and 11.6W for the condenser fan to 4.5W for each)

- Increased condenser and evaporator areas, and

- Better thermal management (reduced load) for the through-the-door feature.

The three groups also added the following groups of design options:

- *Path 1*: 2.54cm (one inch) additional insulation thickness for walls and doors

- *Path 2*: 1.27cm (½ inch) additional insulation thickness for walls and doors, ADC, and improved gaskets

- *Path 3*: Vacuum panels and ADC.

Baseline insulation thicknesses for this unit were 3.8 cm (1.5 inch) for the doors, 5.8 cm (2.3 inch) average for the freezer walls, and 5.1 cm (2.0 inch) average for the fresh food walls.

The fact that there are multiple paths, two of which do not include vacuum panels, suggests that this level of energy use can be achieved cost-effectively. This is corroborated by current sales levels for Energy Star-compliant side-mount refrigerators, which represent about 50 percent of the sales of this product class.[2]

The 508 kWh/year energy use level, the minimum calculated for side-mounts in the TSD, is nearly 25 percent below the 2001 Standard. The single design path for this energy level incorporates Path 1 above plus the following.

- Adaptive Defrost Control.

- Reduced Gasket Heat Leak

If the higher level of efficiency of today's best compressors is taken into consideration, the TSD suggests that a full range of design options not including vacuum panels or variable speed compressors may be able to achieve this energy level for side-mounts.

3.1.3 DOE 1995 TSD Cost Analyses

Manufacturing cost estimates presented in the 1995 TSD for design packages, which meet energy use targets at 15 percent and 25 percent below the 2001 Standard, are summarized in Table 3-2. The cost for the design option package, which is the lowest cost, is presented if more than one design option package meets the energy target.

Table 3-2. DOE 1995 TSD Manufacturing Cost Analysis Summary (1992$)

	Top-Mount *	Side-Mount **
2001 Standard Level Minimum Manufacturing Cost	 $300	 $618
15% Reduction (current Energy Star) Minimum Manufacturing Cost Cost Premium	Note 1 $326 $26	 $658 $40
25% Reduction Minimum Manufacturing Cost Cost Premium	 No data 	Note 2 $671 $53

* Auto defrost, no through-the-door features, 18.2 cu. ft. total volume, and 21.4 cu. ft. adjusted volume.

** Auto defrost, through-the-door features, 21.7 cu. ft. total volume, and 26.2 cu. ft. adjusted volume.

Note 1: The energy use of this design package is 2 percent above Energy Star.

Note 2: The energy use of this design package is 1 percent above the energy use target.

Source: DOE 1995 TSD.

The Department also performed a review of the cost increases associated with the different design options presented in the 1995 TSD. These increases appear, for the most part, to be reasonable and consistent with the Department's understanding of costs for the components and design changes presented, with the exception of vacuum panel costs. For the top-mount unit, the TSD estimates that using 2.54cm- (one inch) thick vacuum panels covering 50 percent of exterior walls and the door increased the unit's cost by $46.65. Based on a unit total surface area of about 6.5m^2 (70ft^2), this yields a vacuum panels cost of less than $14.50/m^2 ($1.40/ft^2). An initial investigation by the Department indicates that current OEM costs for vacuum panels range from $43/m^2 to $54/m^2 ($4/ft^2 to $5/ft^2) for large quantities. In addition, the Department is not familiar with cost projections from vacuum panel vendors below $21/m^2 ($2/ft^2). The total cost impact for a refrigerator-freezer would also include design and process changes required to properly apply the vacuum panels. These costs do not include allowance for vacuum panel breakage during manufacturing. These preliminary data lead to the initial conclusion that the $46.65 incremental vacuum panel cost estimate presented in the TSD is low, likely by at least a factor of two.

3.2 AHAM DATA SUBMITTAL AND CONSOLIDATION

In support of the Department of Energy in this review effort, AHAM collected incremental cost data from its member companies in May 2005. Costs were requested for achieving 15 percent and 25 percent reduction in UEC relative to the current DOE standard for several sizes of refrigerator-freezers of the two most common product classes: top-mount without through-the-door features and side-mount with through-the-door features. Subsequently, AHAM aggregated the data by weighting the individual data by company-level sales volumes for each class and size of units and provided the aggregated data to DOE for review and subsequent analysis. The data request survey provided to manufacturers by AHAM is contained in Appendix A.

Table 3-3 and Table 3-4 summarize the incremental manufacturing costs for the top-mount and side-mount refrigerator-freezers. The "average" column values equal the average incremental cost for all products in that size range weighted by shipment volumes, while the "minimum" and "maximum" values are based on the incremental cost for the basic model of each manufacturer with the lowest and highest incremental cost. The costs include materials, burdened labor, and amortization of capital expenses.[a]

Table 3-3. Incremental Manufacturing Costs for Top-Mounted Refrigerator-Freezers without Through-the-Door Features

	14-17 cu. ft.			18-20 cu. ft.			21-22 cu. ft.		
Energy Use Level	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
15% less energy	$8.00	$19.04	$26.00	$8.00	$17.31	$400.00	$10.00	$21.21	$37.00
25% less energy	$64.00	$187.80	$359.00	$18.00	$54.10	$141.00	$40.00	$78.29	$139.00

Source: AHAM.

Table 3-4. Incremental Manufacturing Costs for Side-Mount Refrigerator-Freezers with Through-the-Door Features

	21-23 cu. ft.			24-26 cu. ft.			27-30 cu. ft.		
Energy Use Level	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
15% less energy	$5.00	$26.88	$95.00	$5.00	$17.67	$105.00	$41.00	$91.92	$105.00
25% less energy	$6.00	$126.40	$219.00	$30.00	$99.63	$305.00	Insufficient Data		

Source: AHAM.

3.2.1 Comparison of AHAM Cost Data with TSD Cost Estimates

The manufacturing cost premium estimates of the 1995 TSD and the AHAM data are compared in Table 3-5 below for the product models and energy use levels for which data is available. In all cases, the TSD estimates are within the range of cost premium estimates provided by AHAM. However, the TSD estimates for the side-mount appear to be high for the 15 percent reduction and low for the 25 percent reduction.

[a] Typically burdened labor is composed of labor and overhead where overhead includes indirect labor for downtime, set-up time, supervisors, materials handling, and clerical. Some other overhead costs such as utilities and insurance might also be included or may be allocated as indirect materials or material burden. Practices for classifying other overhead costs vary by manufacturer.

Table 3-5. Comparison of 1995 TSD and AHAM Manufacturing Cost Premium Estimates

	Top-Mount *	Side-Mount **
15% Reduction (current Energy Star)	Note 1	
1995 TSD Cost Premium [$1992]	$26	$40
AHAM Cost Premium (min.-avg.-max.)	$8 - $17 - $400	$5 - $27 - $95
25% Reduction		Note 2
1995 TSD Cost Premium [$1992]	No data	$53
AHAM Cost Premium (min.-avg.-max.)	$18 - $54 - $141	$6 - $126 - $219

* Auto defrost, no through-the-door features, 18.2 cu. ft. total volume, and 21.4 cu. ft. adjusted volume.
** Auto defrost, through-the-door features, 21.7 cu. ft. total volume, and 26.2 cu. ft. adjusted volume.
Note 1: The energy use of this design package for the TSD cost premium estimate is 2 percent above Energy Star.
Note 2: The energy use of this design package for the TSD cost premium is 1 percent above the energy use target.

3.3 MANUFACTURER INTERVIEWS

Initially, the Department's cost analysis focused on a review of the 1995 TSD and evaluation of the consumer price differential between "matched pairs" of products, i.e., products whose only differences were their efficiency levels (e.g., comparing a unit that performed at the DOE standard level and another unit that met the Energy Star requirements). AHAM and its member companies indicated that the matched pair approach had several limitations, notably that the products may not be true matched pairs (e.g., due to product features), that retail price differences between matched pairs do not necessarily reflect OEM cost differences due to market factors, and that the approach does not consider the full product lines offered by manufacturers. Models, which would have an Energy Star matched pair, would typically be carefully picked to allow for a more cost-effective boost of the efficiency level. Manufacturers noted during structured interviews that they often do not maintain their margins for higher-cost Energy Star units because they believe that consumers do not think that the additional cost can justify relatively modest savings. Non-energy features, however, can often command greater premiums than Energy Star.

During interviews, manufacturers were asked what groupings of design options would be required in order to reduce energy use of top-mount and side-mount refrigerators to levels which are 15 percent and 25 percent below the 2001 Standard. The discussion was helpful to better understand which of the1995 TSD design paths were already implemented. Additionally, the conversations resulted in a better understanding of the design strategies underlying the 2005 AHAM data. The discussion below represents a consolidation of the responses in order to avoid revealing design details for any given manufacturer.

3.3.1 15 Percent Energy Use Reduction

For the most part, achieving a 15 percent energy use reduction is possible with the use of a high-efficiency compressor, high-efficiency fan motors (brushless-DC fan motors) for both the evaporator and condenser fans, and adaptive defrost control. In general, manufacturers indicated that they had to incorporate more energy-efficient features to achieve the reduction for side-mount units than for top-mount units. In some cases, significantly more aggressive design options (i.e. variable-speed compressors and/or vacuum panels) would be required in order to achieve a 15 percent energy use reduction. This is more likely the case with counter-depth (24-

inch-deep) units, which have increased surface/volume ratio, which means that these units have more surface area to transfer heat than more conventional units of the same internal volume.

3.3.2 25 Percent Energy Use Reduction

Achieving 25 percent energy use reduction generally could not be done just by switching to more efficient components. Instead, it requires a reduction in load transmitted through the refrigerator walls and doors. This would be done by increasing wall thickness if possible, but could potentially require the use of vacuum panels. In either case, this involves redesign of product platforms with the associated capital investments required to purchase new manufacturing tooling. Use of variable speed compressors was also mentioned as a possible additionally required design change. All manufacturers indicated that one or more of their refrigerator models could not cost-effectively be brought to the 25 percent reduced energy level and would likely be discontinued.

3.3.3 Bottom-Mount Refrigerators

While most of the analysis discussed in this report addresses top-mount and side-mount refrigerators, one manufacturer pointed out that bottom-mount refrigerators are also an important product class that should be considered. Design options to achieve 15 percent and 25 percent energy use reductions for bottom-mount refrigerators were reported to be similar to those required for top-mount refrigerators.

3.3.4 Platform Changes

It is important to note that many manufacturers would likely take a platform-based approach toward product redesign such that different models built using one platform could achieve both the standard level and a future Energy Star performance level. As discussed in the "Market Impact" section, this is driven by the market need to offer a range of products that can meet both performance levels to serve some key clients, such as major retail chains and the U.S. government. The future Energy Star energy use may be 25 percent below the 2001 Standard. Hence, it would be expected that, if a 15 percent energy use reduction is mandated by DOE, manufacturers would need to implement wall thickness increases in order to be able to meet both 15 percent and 25 percent reduction levels with a given production platform (the 25 percent models would include more high-efficiency components).

3.3.5 Intellectual Property

Although manufacturers did not have major concerns about intellectual property rights impeding access to technologies used to enhance efficiency, a few manufacturers did note that one (foreign) company owns patents related to linear compressors, a variable-capacity compressor technology which may have better efficiency than conventional rotary-motor reciprocating compressors.

REFERENCES

1. U.S. Department of Energy, *Technical Support Document: Energy Efficiency Standards for Consumer Products: Refrigerators, Refrigerator-Freezers, & Freezers*, July 1995. Washington, DC. Report No. DOE/EE-0064.

2. Association of Home Appliance Manufacturers, *Summary Data Tables: Refrigerator-Freezer Data Collection for Cost/Efficiency Information for DOE Petition*, 2005. Information provided by the Association of Home Appliance Manufacturers (AHAM) to the U.S. Department of Energy, May 13, 2005.

CHAPTER 4. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

Increasing the energy efficiency of a product to comply with a standard affects the costs of purchasing and operating the product. Higher-efficiency products usually have higher installed costs and lower operating costs. The Department performed a life-cycle cost (LCC) and payback period (PBP) analysis to help determine whether the operating cost savings of potential new standards for refrigerator-freezers are sufficient to justify the higher purchase price.

For the purposes of this analysis, the Department analyzed the LCC and PBP of amended energy conservation standards for the following two product classes of refrigerators, refrigerator-freezers, and freezers: (1) top-mounted freezer without through-the-door (TTD) ice service, automatic defrost and (2) side-mounted freezer with TTD ice service, automatic defrost. The Department analyzed two standard levels: (1) product with 15 percent less annual energy consumption than the baseline product (i.e., a product meeting current energy conservation standards) and (2) a product with 25 percent less annual energy consumption than the baseline product. The Department assumed baseline products to equal the maximum energy consumption allowed by current energy conservation standards. Refrigerator-freezers with 15 percent less energy consumption correspond to products meeting current Energy Star requirements. Refrigerator-freezers with 25 percent less energy consumption correspond to products meeting potential future Energy Star levels, assuming new standards are set at existing Energy Star levels.

4.1 LIFE-CYCLE COST METHODOLOGY

The Department calculated the LCC by adding the installed cost and all the operating costs until the end of the product lifetime as shown in Equation 4.1. The total installed cost for a refrigerator-freezer includes the consumer retail price and the installation cost. The operating costs include the electricity expense and any repair and maintenance costs. The equation discounts future operating costs to the year of installation.

$$LCC = P + \sum \frac{O_t}{(1+r)^t} \qquad \textbf{Eq. 4.1}$$

where:

P = total installed cost ($),
Σ = sum over analysis period,
O_t = annual operating cost ($),
r = discount rate for costs, and
t = lifetime (years).

The LCC savings is the difference between the LCC of the baseline (i.e., the product meeting current energy conservation standards) and the LCC of the product meeting new standards. For purposes of this analysis, the Department assumed the installation, repair, and maintenance costs were equal to zero.

Figure 4-1 illustrates the cumulative costs, which include the initial total installed cost and the discounted annual operating costs, over the equipment lifetime for a hypothetical baseline product (no standards) and a product meeting new standards. Typically, the standards case has a higher initial total installed cost than the baseline.

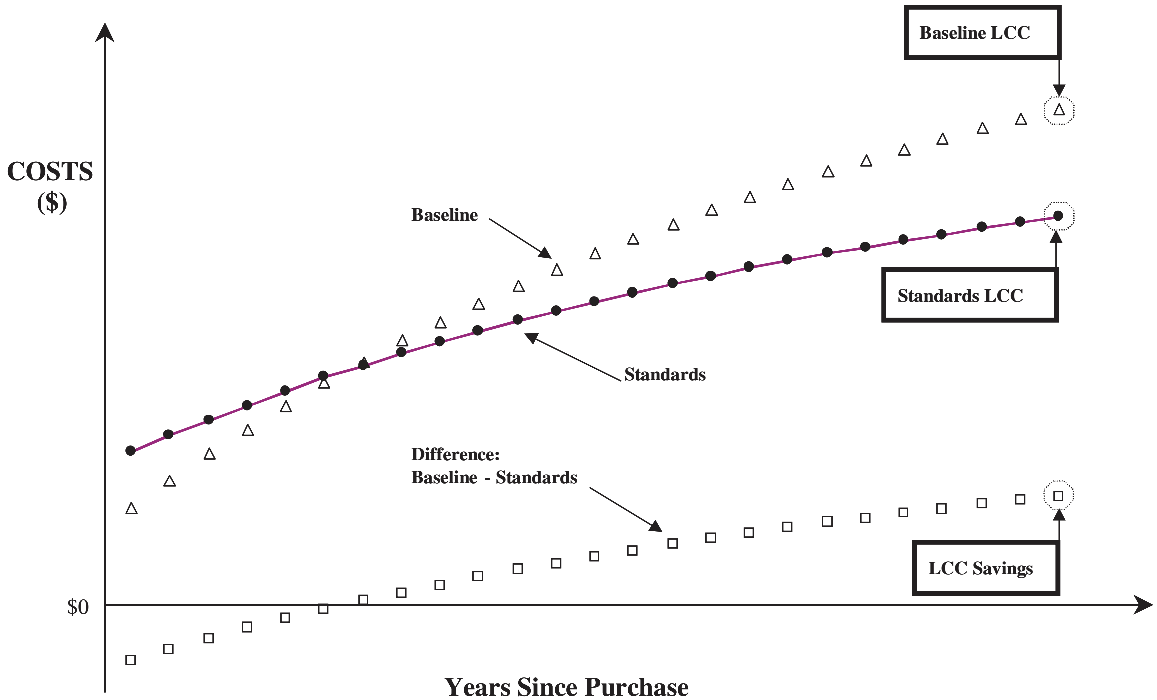

Figure 4-1. Illustration of LCC for Baseline and Standards

Over the years that the refrigerator is in use, the system incurs electricity costs. The baseline product consumes more electricity than the product in the standards case, so the total LCC is generally higher for the baseline product than for the product meeting new standards.

Figure 4-2 illustrates the inputs, calculated values, and outputs of the LCC analysis. A representative value or range of values represents each input. The Department annotated data sources in the LCC and PBP spreadsheet model and fully documented them in this chapter.

The Department performed the LCC and PBP analysis using representative values for product retail prices and lifetimes, energy costs, energy usage, and discount rates. The following sections discuss and document the LCC inputs.

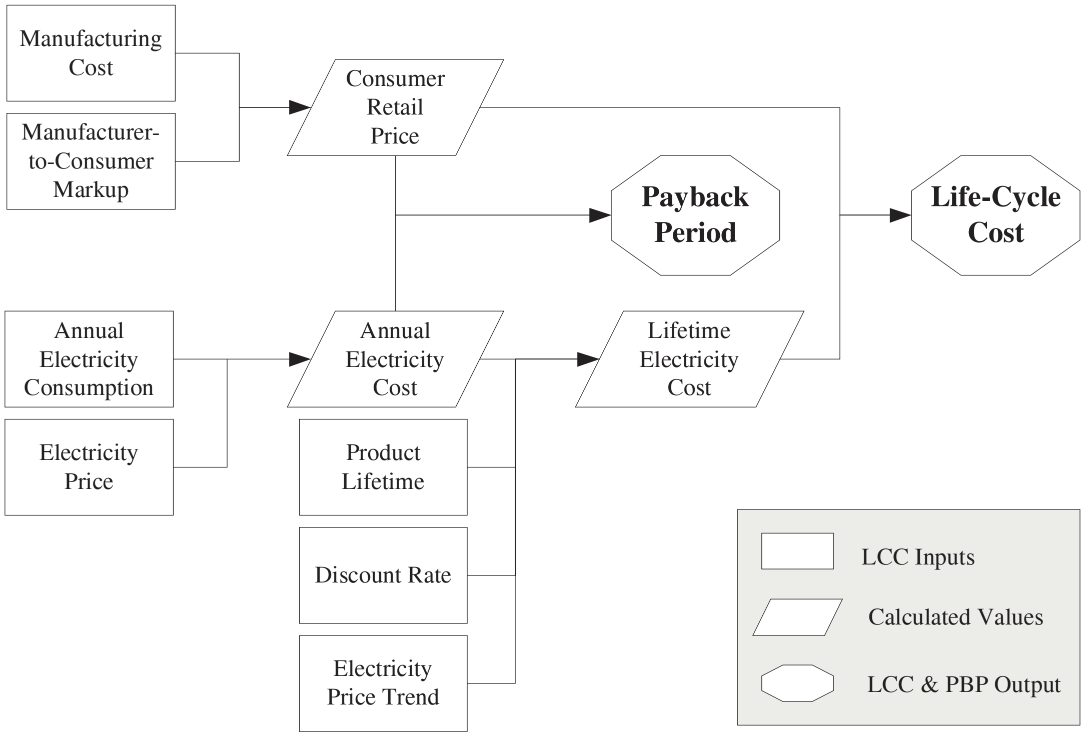

Figure 4-2. Flow Diagram of Life-Cycle Cost and Payback Period Analysis

4.2 CONSUMER RETAIL PRICE

The consumer retail price represents the price to the consumer of purchasing a refrigerator-freezer. The Department determined the consumer retail price of more-efficient refrigerator-freezers by first establishing the retail price of baseline products (i.e., products meeting current energy conservation standards) and then establishing the incremental retail price associated with the more efficient products. The Department determined two sets of incremental retail prices: one set based on incremental manufacturing costs and the other set based on a regression analysis of refrigerator-freezer sales data. The Department also conducted an analysis of focused matched pairs of refrigerator-freezers to determine the incremental price of more efficient products. The focused matched pairs consisted of two models where most features were similar with the exception that one model met Energy Star and the other model did not.

4.2.1 Baseline Retail Price

The Department determined the retail prices associated with baseline top-mount and side-mount refrigerator-freezers through an analysis of retail prices from The NPD Group.[1] The NPD Group dataset includes information about the average price and model number of more than 2000 refrigerator models sold in 2004 in the United States. The data also include information about the refrigerator brand, manufacturer, attributes (e.g., total refrigerated volume, number and type of shelves), and sales, and whether each model has an Energy Star rating.

The NPD Group dataset includes information on 535 top-mount and 629 side-mount refrigerator-freezer models. Summary information on these models is included in Appendix B. The Department used price and sales information about these models to select groups of basic top-mount and side-mount refrigerator-freezers. The Department defined basic refrigerator-freezers from the distribution of lower-priced, high-selling models.

As shown in Figure 4-3, the sales-weighted distribution of top-mount models indicated a price grouping of 387 models under $600 (over 90 percent of sales). As a result, the Department defined this grouping of 387 models as basic top-mount models.

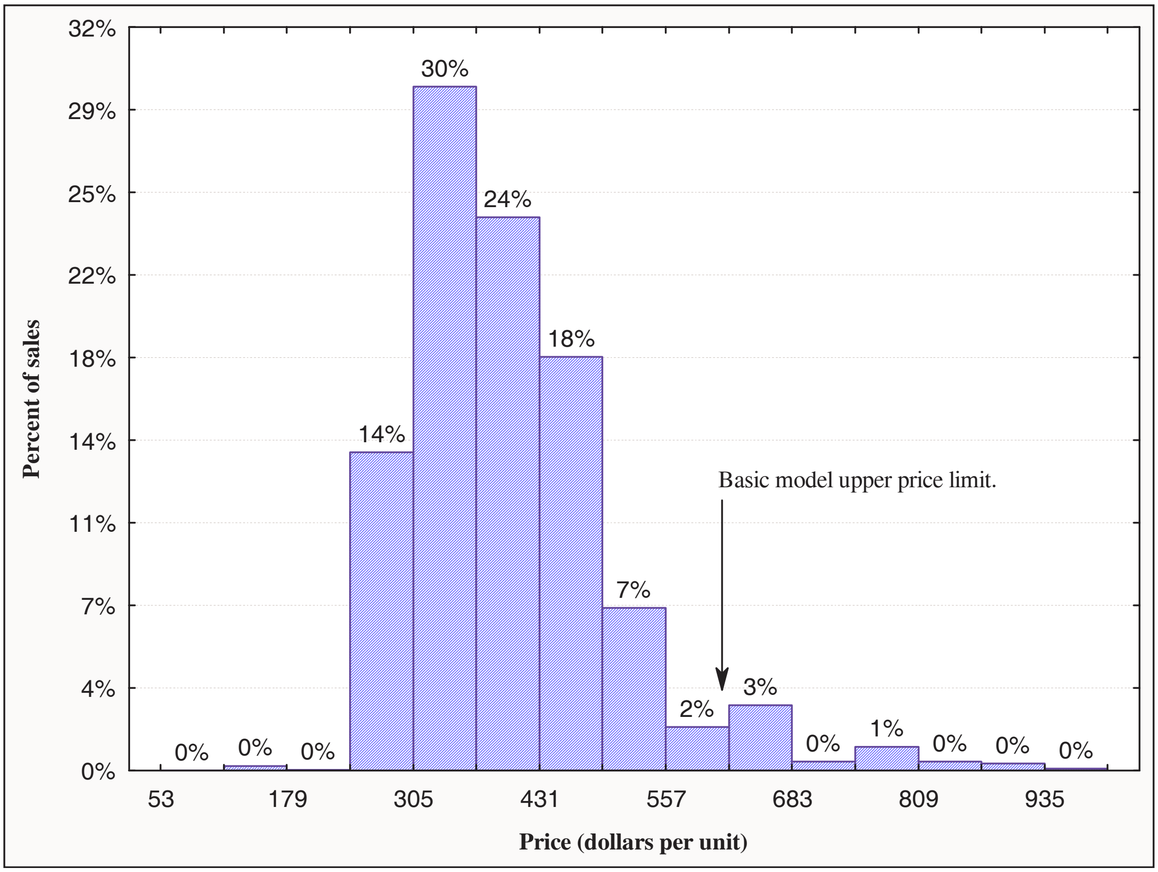

Figure 4-3. Sales by Retail Price: Refrigerator-Freezers with Top-Mount Freezer

Of the 387 top-mount models under $600, 262 models are without TTD ice service and do not meet current Energy Star levels. Thus, the Department considered these 262 models to be baseline models (i.e., models just meeting current energy conservation standards). Table 4-1 shows the sales-weighted baseline prices associated with three capacity size ranges of top-mount refrigerator-freezers. Capacities are in total refrigerated volume (i.e., fresh food compartment volume plus freezer compartment volume).

Table 4-1. Baseline Retail Prices: Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service

	14-17 cu. ft.	18-20 cu. ft.	21-22 cu. ft.
Baseline Retail Price	$329	$386	$457

Source: The NPD Group/NPD Houseworld – POS.

For side-mount models, Figure 4-4 shows the sales-weighted distribution indicating a price grouping of 302 models under $1100 (70 percent of sales). As a result, the Department defined this grouping of 302 models as basic side-mount models.

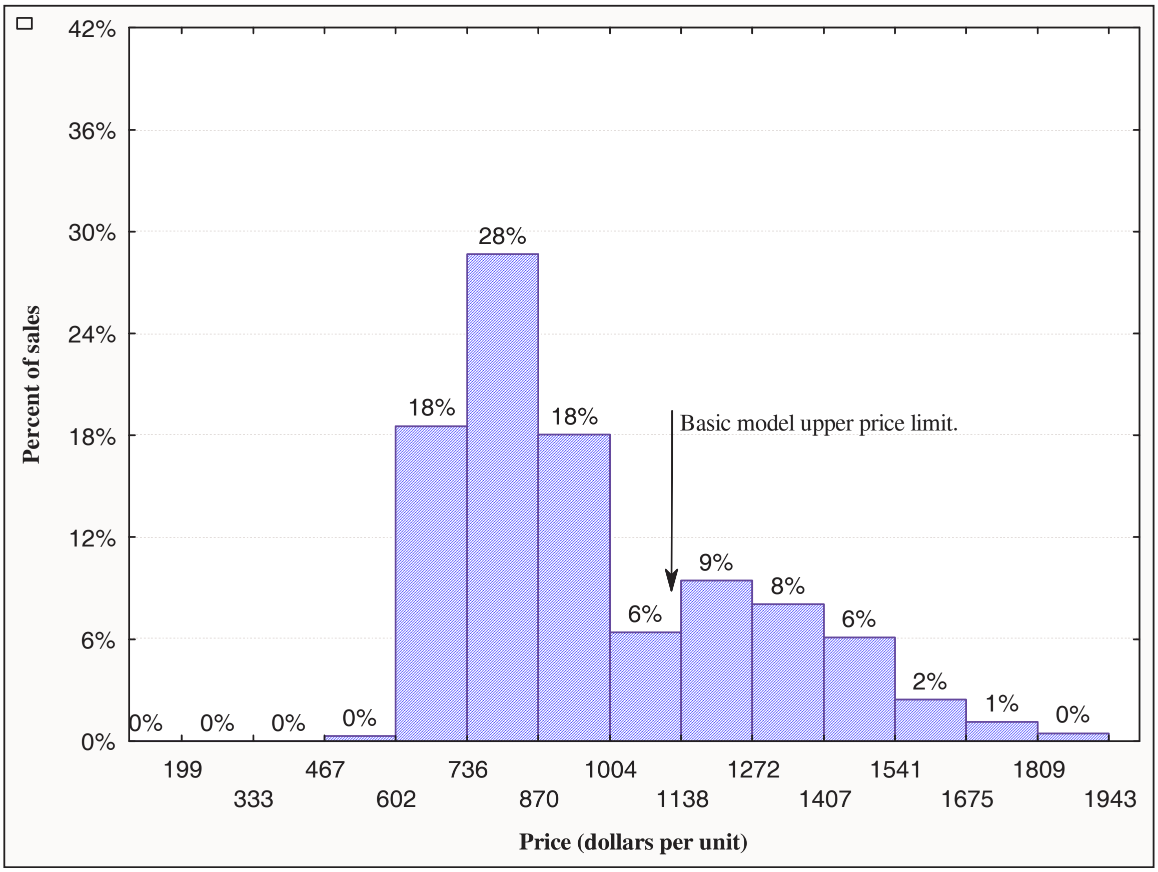

Figure 4-4. Sales by Retail Price: Refrigerator-Freezers with Side-Mount Freezer

Of the 302 top-mount models under $1100, 143 models feature TTD ice service and do not meet current Energy Star levels. Thus, the Department considered these 143 models to be baseline models. Table 4-2 shows the sales-weighted baseline prices associated with three capacity size ranges of side-mount refrigerator freezers. Capacities are in total refrigerated volume.

Table 4-2. Baseline Retail Prices: Refrigerator-Freezers with Side-Mount Freezer and with TTD Ice Service

	14-17 cu. ft.	18-20 cu. ft.	21-22 cu. ft.
Baseline Retail Price	$702	$789	$926

Source: The NPD Group/NPD Houseworld – POS.

4.2.2 Incremental Retail Prices based on Incremental Manufacturing Costs

4.2.2.1 Incremental Manufacturing Costs

As detailed in chapter 2 on the engineering analysis, the Association of Home Appliance Manufacturers (AHAM) collected manufacturing cost data from manufacturers of refrigerator-freezers.[2] The data provided the incremental manufacturing cost of achieving energy use levels 15 percent and 25 percent lower than current baseline levels. The incremental manufacturing cost data provided by AHAM to the Department were for three size ranges of refrigerator-freezers with top-mounted freezers and without TTD ice service, as well as three size ranges of refrigerator-freezers with side-mounted freezer and with TTD ice service. For each capacity size category, a minimum, average, and maximum incremental manufacturing cost was provided. The incremental manufacturing cost data are summarized in Table 4-3 for top-mount refrigerator-freezers and in Table 4-4 for side-mount refrigerator-freezers.

Table 4-3. Incremental Manufacturing Costs: Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service

	14-17 cu. ft.			18-20 cu. ft.			21-22 cu. ft.		
Energy Use Level	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
15% less energy	$8.00	$19.04	$26.00	$8.00	$17.31	$400.00	$10.00	$21.21	$37.00
25% less energy	$64.00	$187.80	$359.00	$18.00	$54.10	$141.00	$40.00	$78.29	$139.00

Source: AHAM.

Table 4-4. Incremental Manufacturing Costs: Refrigerator-Freezers with Side-Mount Freezer and with TTD Ice Service

	21-23 cu. ft.			24-26 cu. ft.			27-40 cu. ft.		
Energy Use Level	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
15% less energy	$5.00	$26.88	$95.00	$5.00	$17.67	$105.00	$41.00	$91.92	$105.00
25% less energy	$6.00	$126.40	$219.00	$30.00	$99.63	$305.00	Insufficient Data		

Source: AHAM.

4.2.2.2 Manufacturer-to-Consumer Markup

The manufacturer-to-consumer markup is a multiplier used to convert manufacturing costs into consumer retail prices. For this analysis, the Department estimated this markup from a prior technical support document (TSD) the Department published in 1995 to assess whether amended energy conservation standards were warranted for refrigerator-freezers.[3] Table 4-5 shows the manufacturing costs, retail prices, and deduced markups developed from this prior analysis for baseline top-mount and side-mount refrigerator freezers. The deduced markup is the retail price divided by the manufacturing cost.

Table 4-5. Manufacturer-to-Consumer Markups for Refrigerator-Freezers

Product Class	Manufacturing Cost (1992$)	Retail Price (1992$)	Deduced Markup
Top-Mount Freezer without TTD Ice Service	$259.53*	$554.67**	2.14
Side-Mount Freezer with TTD Ice Service	$597.41†	$1161.51††	1.94

* **Source:** DOE 1995 TSD. Table 3.5.; ** **Source:** DOE 1995 TSD. Table 4.1.

† **Source:** DOE 1995 TSD. Table 3.8.; †† **Source:** DOE 1995 TSD. Table 4.4.

Because the deduced markups for both of the above product classes of refrigerator-freezers are approximately 2.0, the Department chose to use a manufacturer-to-consumer markup of 2.0 for this analysis. The Department assumed this markup to include all sales taxes.

4.2.2.3 Resultant Incremental Retail Prices

Based on the manufacturer-to-consumer markup of 2.0, the incremental manufacturing costs in Tables 4-3 and 4-4 can be converted to incremental consumer retail prices. The incremental retail price data are summarized in Table 4-6 for top-mount refrigerator-freezers and in Table 4-7 for side-mount refrigerator-freezers.

Table 4-6. Manufacturing Cost-Based Incremental Retail Prices: Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service

	14-17 cu. ft.			18-20 cu. ft.			21-22 cu. ft.		
Energy Use Level	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
15% less energy	$16.00	$38.08	$52.00	$16.00	$34.62	$800.00	$20.00	$42.42	$74.00
25% less energy	$128.00	$375.60	$718.00	$36.00	$108.20	$282.00	$80.00	$156.58	$278.00

Table 4-7. Manufacturing Cost-Based Incremental Retail Prices: Refrigerator-Freezers with Side-Mount Freezer and with TTD Ice Service

	21-23 cu. ft.			24-26 cu. ft.			27-30 cu. ft.		
Energy Use Level	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
15% less energy	$10.00	$53.76	$190.00	$1.00	$35.34	$210.00	$82.00	$183.84	$210.00
25% less energy	$12.00	$252.80	$438.00	$60.00	$199.26	$610.00	Insufficient Data		

4.2.3 Incremental Retail Prices based on Regression Analysis

The Department performed a regression analysis of basic top-mount and side-mount refrigerator-freezer models from The NPD Group dataset to estimate the incremental retail price of current Energy Star compliant products (i.e., products with 15 percent less energy consumption than baseline products). As described earlier in section 3.2.1, *Baseline Retail Price*, there are 387 basic top-mount models and 302 basic side-mount models.

The Department developed regression equations to determine the retail price increment due to Energy Star. It developed a "short" regression equation with retail price as a function of Energy Star and total capacity as well as a "long" regression equation with retail price as a function of Energy Star, total capacity, attributes (i.e., TTD services, icemaker, water filter, drawer, and shelf specifications) and brand name. The Department developed the "long" regression equations with and without weighting refrigerator-freezer models by sales in 2004.

As shown in Table 4-8, the current Energy Star rating adds between \$39 and \$47 to the price of a basic top-mount refrigerator-freezer and between \$60 and \$85 to the price of a basic side-mount refrigerator-freezer.

Table 4-8. Regression Analysis Results on the Incremental Retail Price of Energy Star

	ENERGY STAR® Coefficient $\Delta_{price}/\Delta_{ENERGY\ STAR}$	Regression fit – R^2	Number of Observations
Top-Mount Equations			
"Short" Regression: Energy Star, total capacity			
Price	\$47.40	0.24	387
"Long" Regression: Energy Star, total capacity, attribute, and brand name			
Price	\$44.39	0.42	387
Price, sales-weighted	\$39.30	0.83	387
Side-Mount Equations			
"Short" Regression: Energy Star, total capacity			
Price	\$65.80	0.03	302
"Long" Regression: Energy Star, total capacity, attribute, and brand name			
Price	\$60.40	0.11	302
Price, sales-weighted	\$84.90	0.51	302

Source: The NPD Group/NPD Houseworld – POS.

The results of the complete variable regression equations are included in Appendix B. The estimated coefficients of the focus variables are significant and have the expected sign in all but one instance.[b] The attribute variable coefficients have the expected sign in most cases, but

[b] The statistic of significance in the un-weighted regressions is the t statistic, defined as the estimated value of the coefficient divided by its estimated standard deviation. Commonly, a t statistic over 2 suggests a coefficient to be greater than zero with a high degree of confidence. In the sales-weighted regressions, a similar z statistic is used to denote significance of the estimated coefficient.

are less often significant. Although all the variables in the sales-weighted regressions are shown to be significant at the 95 percent confidence level, the test of significance is biased upwards because the dependent variable (retail price) is averaged over all model sales.

The Department chose the non-sales-weighted “long” regression equation as providing the most representative retail price increment for Energy Star (i.e., $44.39 for top-mount and $60.40 for side-mount). As just noted, the sales-weighted regressions include a bias, since the retail price associated with any given model is actually an average value averaged across all sales of the given model. Thus, the results from the sales-weighted regression are biased to over-represent the average retail price rather than the actual retail price. The Department chose the non-sales-weighted “long” regression equation over the non-sales-weighted “short” regression equation because the attribute and brand names variables influence the retail price of refrigerator models. Including these variables tends to improve the accuracy of the retail price coefficient.

The retail price increment for Energy Star determined from the non-sales-weighted “long” regressions is associated with specific capacities (i.e., total refrigerated volumes). For top-mount refrigerator-freezers the $44.39 price increment is for an 18.3 cubic foot capacity unit while, for side-mount products, the $60.40 price increment is for a 24.1 cubic foot capacity unit. The non-sales-weighted “long” regressions also demonstrate that the size or total capacity of the refrigerator-freezer impacts the price. The price coefficient for capacity is $5.97 per cubic foot and $6.30 per cubic foot for top-mount and side-mount refrigerator-freezers, respectively. Because the regression analysis provided a capacity price increment as well as an Energy Star price increment, the Department was able to generate incremental retail prices for each of the size categories in which manufacturing cost data were submitted (refer back to Table 4-3 and Table 4-4 for the size categories). Equations 4.2 and 4.3 provide the expressions for determining the retail price increment of Energy Star for top-mount and side-mount refrigerator-freezers, respectively.

$$TM_{PRICE\ ESTAR} = \$44.39 + (TM_{CAPACITY} - 18.3) \bullet \$5.97 \qquad \textbf{Eq. 4.2}$$

where:

$TM_{PRICE\ ESTAR}$	= top-mount Energy Star price increment at $TM_{CAPACITY}$,
$44.39	= Energy Star price increment for top-mount at 18.3 cu. ft.,
$TM_{CAPACITY}$	= capacity in cu. ft. of top-mount refrigerator-freezer,
18.3	= top-mount capacity for $44.39 Energy Star price increment, and
$5.97	= top-mount price coefficient for capacity per cu. ft.

$$SM_{PRICE\ ESTAR} = \$60.40 + (SM_{CAPACITY} - 24.1) \bullet \$6.30 \qquad \textbf{Eq. 4.3}$$

where:

$SM_{PRICE\ ESTAR}$	= side-mount Energy Star price increment at $SM_{CAPACITY}$,
\$60.40	= Energy Star price increment for side-mount at 24.1 cu. ft.,
$SM_{CAPACITY}$	= capacity in cu. ft. of side-mount refrigerator-freezer,
24.1	= side-mount capacity for \$60.40 Energy Star price increment, and
\$6.30	= side-mount price coefficient for capacity per cu. ft.

Table 4-9 and Table 4-10 show the incremental retail price of achieving current Energy Star levels (i.e., 15 percent lower energy consumption than baseline products) for size categories in which manufacturing costs were submitted. To calculate the price increments shown in the tables below, the Department assumed the average value of the capacity range is the representative size (e.g., 15.5 cubic feet for the 14–17 cubic foot size category). Note that the Department could not establish the price increment of products with 25 percent less energy, as these products are currently not sold in significant numbers and were therefore not included in the dataset provided by The NPD Group.

Table 4-9. Regression Analysis Incremental Retail Prices: Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service

	14-17 cu. ft.	18-20 cu. ft.	21-22 cu. ft.
15% less energy	\$27.67	\$48.57	\$63.49

Source: The NPD Group/NPD Houseworld – POS.

Table 4-10. Regression Analysis Incremental Retail Prices: Refrigerator-Freezers with Side-Mount Freezer and with TTD Ice Service

	21-23 cu. ft.	24-26 cu. ft.	27-40 cu. ft.
15% less energy	\$47.17	\$66.07	\$88.12

Source: The NPD Group/NPD Houseworld – POS.

4.2.4 Comparison of Manufacturing Cost-Based and Regression Analysis Retail Prices

Figure 4-5 and Figure 4-6 provide the consumer retail price estimates for top-mount and side-mount refrigerator-freezers, respectively. For the retail prices based on manufacturing costs, the figures provide prices based not only on average cost estimates, but for minimum and maximum cost estimates as well. Retail price comparisons are only possible for the 15 percent less energy standard level, since the regression analysis was only able to generate prices for this energy consumption level. In general, the retail price estimates based on the average manufacturing cost estimates and the regression analysis are similar. For top-mount refrigerator-freezers, the difference in the retail price estimates between the two approaches ranges from \$11 to \$21. For side-mount refrigerator-freezers, the difference between the two approaches is broader. While the 21–23 and 24–26 cubic foot size categories have price differences of $7 and $31, respectively, the 27–30 cubic foot size category has a price difference of $96.

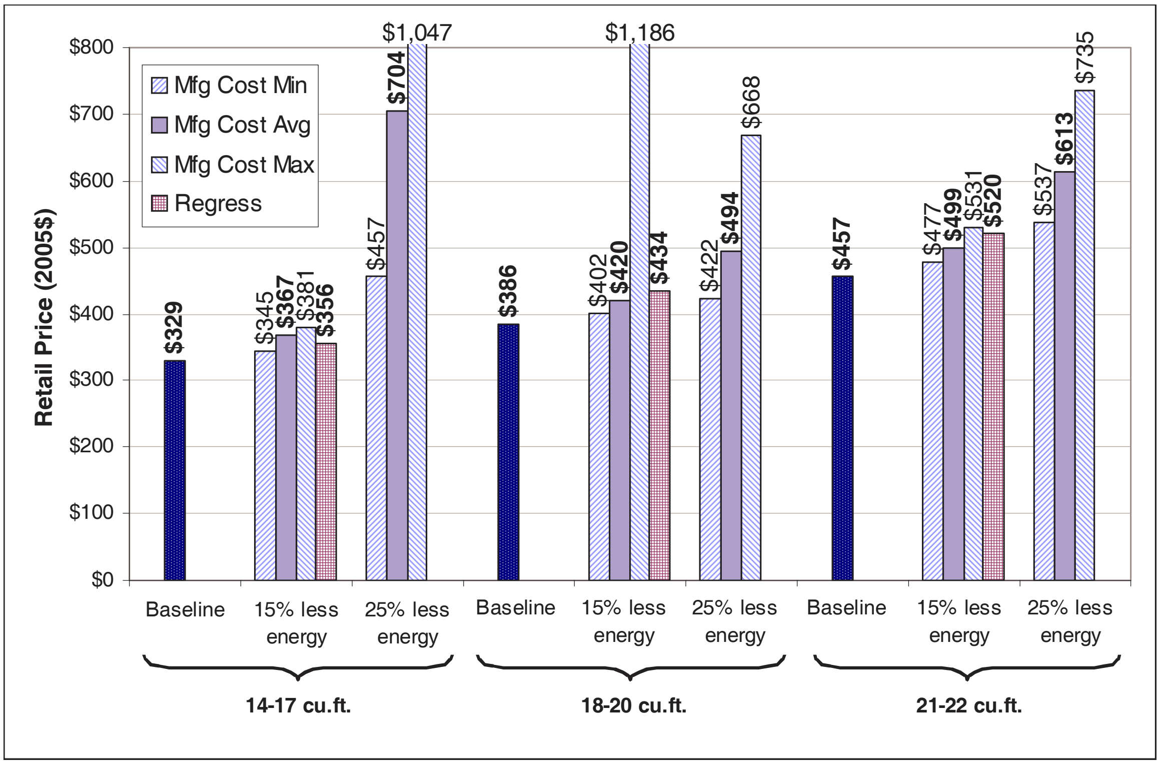

Figure 4-5. Retail Prices for Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service

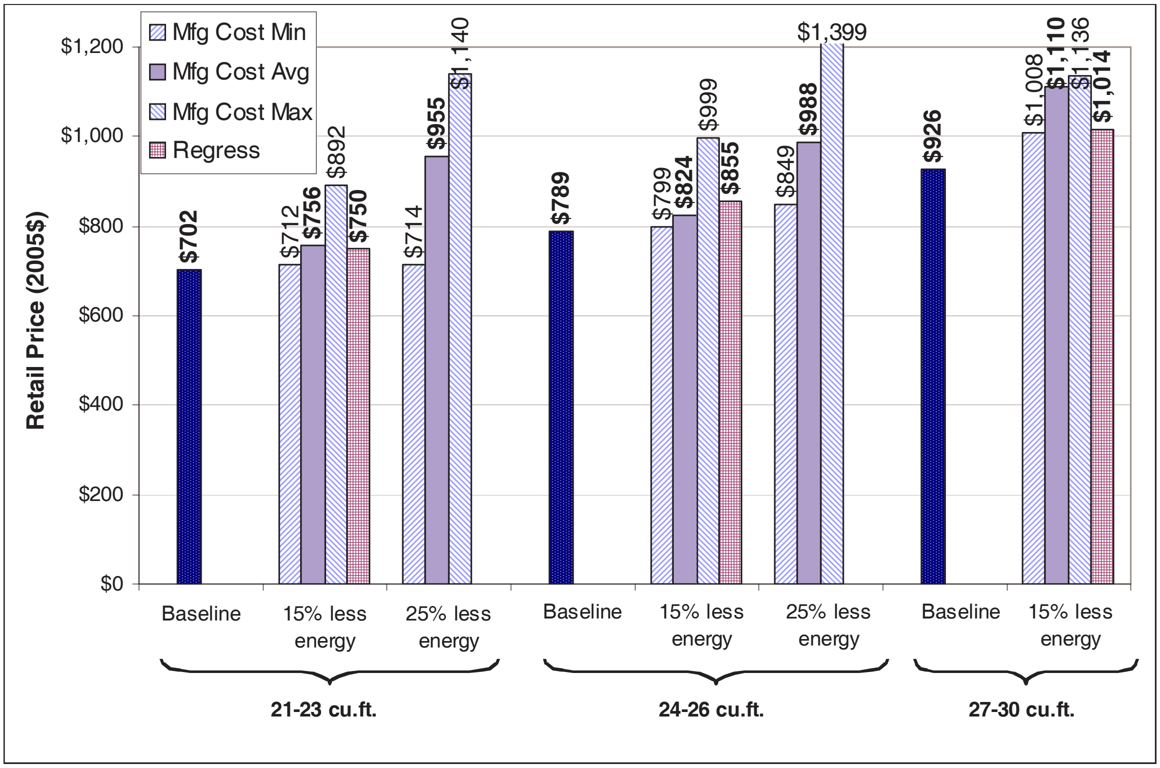

Figure 4-6. Retail Prices for Refrigerator-Freezers with Side-Mount Freezer and with TTD Ice Service

4.2.5 Focused Matched Pair Analysis

The Department conducted a focused matched pair analysis to quantify the difference in consumer retail price for a matched pair of refrigerators that are very similar in features except for annual energy consumption.

Both manufacturer and retailer web sites provide detailed information on features for each model, including retail price and energy consumption. The Department selected eight pairs of top-mount models and four pairs of side-mount models for comparison. The process it used for finding matching pairs was as follows:

- At the manufacturer's web site, the Department narrowed the selection shown to those having a common capacity or total refrigerated volume.
- The Department examined other features such as whether or not a refrigerator had an ice-maker, water filter, or TTD ice and/or water service. Other features considered in comparisons included glass versus wire shelves, and the number of shelves in the refrigerator and freezer compartments.
- The Department obtained fresh food volumes and freezer volumes from the manufacturer's web site and calculated an adjusted total volume based on the Department's test procedure. The Department used the adjusted total volume to calculate

the current maximum allowable annual electricity consumption for each refrigerator-freezer. The Department also determined the Energy Star maximum allowable electricity consumption threshold. (A detailed discussion of adjusted total volume and annual electricity consumption is in section 3.3.1.1.)

- The Department found no two models where, except for one being Energy Star, all other features were the same. Therefore, the Department used its judgment to select two models close enough for comparison. To eliminate price difference due to color, DOE used only the color white for comparison.

Once it had selected the matched pairs, the Department entered the pertinent data on energy consumption and features into a spreadsheet and determined the difference in energy consumption for each pair. It collected retail price data from nine web sites, including the manufacturer and eight retailers. The retail prices used by the Department were the manufacturer's suggested retail price and, at the retail sites, the advertised selling price. The detailed energy consumption, features, and retail price data for the matched pairs are in Appendix C.

Table 4-11 and Table 4-12 summarize the results for the top-mount refrigerator-freezers and the side-mount refrigerator-freezers, respectively. The model designated as Baseline achieves or exceeds the current energy efficiency standards but is not an Energy Star model. In the "Delta Price" column, the range refers to the retail prices from the web sites. The number of web sites giving retail prices varied among the models. Where no range is given, the retail price is that from the manufacturer. The "Average Incremental Price" for Energy Star refers to the difference between the average retail prices of each matched pair.

Table 4-11. Comparison of Matched Pairs: Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service

Category	Brand	Model Number	Total Refrigerated Volume *(cubic feet)*	Delta Energy Use *(kWh/yr & Percent)*	Delta Price Range	Delta Price Average	Average Incremental Price for Energy Star *(Percent)*
Baseline Energy Star	GE	GTS22KBPWW GTH22KKBRWW	21.7 21.7	81 15.3%	$30–$50	$40	5.4%
Baseline Energy Star	Frigidaire	FRT21C5A FRT21HC5D	20.5 20.6	77 15.1%	$95–$100	$98	22.3%
Baseline Energy Star	Whirlpool	ET1MHKXM ET1MTEXM	21.0 21.0	71 13.8%	$44–$160	$93	17.0%
Baseline Energy Star	Kenmore	74192 74172	20.6 20.6	77 15.1%	$50–$180	$115	23.0%
Baseline Energy Star	Whirlpool	ET8MHKXM ET8FTEXM	18.2 18.2	72 14.9%	$0–$60	$44	8.8%
Baseline Energy Star	GE	GTS18KBPWW GTH18BRWW	17.9 17.9	72 14.9%	$20–$25	$23	3.4%
Baseline Energy Star	GE	GTR16BBSRWW GTH16BBSLWW	15.7 15.7	69 15.2%	$30	$30	5.2%
Baseline Energy Star	GE	GTR15BBR GTH15BBR	14.9 14.9	67 15.0%	$0–$30	$15	2.7%

Table 4-12. Comparison of Matched Pairs: Refrigerator-Freezers with Side-Mount Freezer and with TTD Ice Service

Category	Brand	Model Number	Total Refrigerated Volume *(cubic feet)*	Delta Energy Use *(kWh/yr & Percent)*	Delta Price Range	Delta Price Average	Average Incremental Price for Energy Star *(Percent)*
Baseline Energy Star	GE Profile	PSI23NGPWW PSH23PGRWW	22.6 22.6	102 14.9%	$250	$250	9.6%
Baseline Energy Star	GE	GSS25KGPWW GSH25KGRWW	24.9 25.0	105 14.7%	($3)–$50	$24	1.9%
Baseline Energy Star	Frigidaire	GLRS267ZD GLHS268ZD	25.7 26.0	109 15.0%	$100– $160	$126	11.9%
Baseline Energy Star	Amana	ASD2622HRW ASD2624HEW	25.6 25.6	88 12.5%	$50–$100	$62	6.7%

The results from Table 4-11 and Table 4-12 show that the difference in energy use between Baseline and Energy Star models in each matched pair is similar among the pairs—generally around 15 percent. The difference in retail price (incremental retail price) varies considerably, however.

There is no clear evidence that differences in features between a pair have a consistent effect on price.[c] Pricing differences among retailers appears to be a factor. For some pairs, the incremental price varied considerably among the web sites. It may be the case that the increased retail price of an Energy Star refrigerator is affected by marketing decisions based on what consumers are willing to pay for the Energy Star designation. Among the top-mount models, the smaller-capacity pairs generally show a lower percentage incremental price than the larger pairs. Also, the larger models have a higher incremental price for Energy Star but also have higher incremental electricity consumption savings.

This matched pair analysis shows that: (1) there is a large variation in the incremental retail price among matched pairs for a similar percentage improvement in energy efficiency, and (2) the results are too varied to establish a clear relationship between retail price and efficiency. Therefore, the Department believes that the matched pair analysis can best be used as a reality check on the other two methods used to estimate consumer retail prices (i.e., the manufacturing-cost-based method and the regression analysis). The incremental retail prices from the focused matched pair analysis generally fall within the range of prices from the manufacturing-cost-based method and the regression analysis.

4.3 LIFETIME ELECTRICITY COST

The lifetime electricity cost includes the annual electricity costs discounted over the product lifetime at an appropriate discount rate. Elements of the Department's methodology for performing this analysis are as follows:

- The analysis period starts in 2010, the assumed start year for possible new energy conservation standards.
- The analysis uses electricity prices projected over the analysis period (see section 3.3.4, Electricity Price Trends).
- The analysis discounts energy cost to the assumed start year for standards (2010).
- All monetary results are in 2005$.

4.3.1 Annual Electricity Cost

The operating cost is the sum of the annual electricity costs plus any replacement or maintenance costs. The annual electricity cost is the product of the annual electricity consumption times the electricity price for any given year.

4.3.1.1 Annual Electricity Consumption

The Department calculated the annual electricity consumption (also called unit energy consumption) for the capacity size categories for which manufacturing cost data were provided. As noted earlier (section 3.2.2.1) manufacturing cost data were provided for three size ranges for

[c] Examination of the prices at manufacturer web sites indicated that, for models of similar capacity, those with more features did not consistently have a higher price.

both top-mount and side-mount refrigerator-freezers. The size ranges were based on total refrigerated volume (i.e., fresh food compartment volume plus freezer compartment volume).

The annual electricity consumption for refrigerator-freezers is a function of the adjusted total volume rather than the total refrigerated volume. The equation for calculating the adjusted total volume is:[4]

$$Vol_{adj} = Vol_{refrig} + 1.63 \bullet Vol_{freezer} \qquad \textbf{Eq. 4.4}$$

where:

Vol_{adj}	= adjusted total volume in cubic feet,
Vol_{refrig}	= fresh food compartment volume in cubic feet,
1.63	= adjustment factor, and
$Vol_{freezer}$	= freezer compartment volume in cubic feet.

The Department had to determine representative freezer-volume-to-total-refrigerated-volume (FV-TRV) ratios for each refrigerator-freezer size range to determine the adjusted total volume. The Department determined representative ratios from the California Energy Commission's (CEC) appliance database.[5] For refrigerator-freezers sold in California, the appliance database provides the fresh food, freezer, and total volumes. Table 4-13 and Table 4-14 provide the minimum, average, and maximum FV-TVR ratios for top-mount and side-mount refrigerator-freezers, respectively.

Table 4-13. Freezer-Volume-to-Total-Refrigerated-Volume: Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service

Total Refrigerated Volume Range (cu. ft.)	Freezer Volume-to-Total Refrigerated Volume		
	Minimum Ratio	Average Ratio	Maximum Ratio
14-17	0.196	0.265	0.295
18-20	0.222	0.267	0.315
21-22	0.292	0.298	0.308

Source: CEC.

Table 4-14. Freezer-Volume-to-Total-Refrigerated-Volume: Refrigerator-Freezers with Side-Mount Freezer and with TTD Ice Service

Total Refrigerated Volume Range (cu. ft.)	Freezer Volume-to-Total Refrigerated Volume		
	Minimum Ratio	Average Ratio	
21-23	0.295	0.350	0.452
24-26	0.337	0.379	0.399
27-30	0.351	0.373	0.391

Source: CEC.

With the FV-TVR ratio known, the Department calculated the adjusted total volume. For each size range, the Department used the mid-point of the range as the representative total refrigerated volume, which, when coupled with the representative value for the FT-TVR ratio, it used to calculate the adjusted total volume. Table 4-15 and Table 4-16 provide the representative adjusted total volumes, as well as the components necessary for determining them, for top-mount and side-mount refrigerators, respectively. The Department based the adjusted total volumes on the average value for the FV-TVR ratio from Table 4-13 and Table 4-14.

Table 4-15. Adjusted Total Volumes: Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service

Total Refrigerated Volume Range	Mid-Point of Total Refrigerated Volume Range	Average Freezer-Volume-to-Total-Refrigerated-Volume	Freezer Volume	Fresh Food Volume	Adjusted Total Volume
(cubic feet)	(cubic feet)		(cubic feet)	(cubic feet)	(cubic feet)
14-17	15.5	0.265	4.1	11.4	18.1
18-20	19.0	0.267	5.1	13.9	22.2
21-22	21.5	0.298	6.4	15.1	25.5

Table 4-16. Adjusted Total Volumes: Refrigerator-Freezers with Side-Mount Freezer and with TTD Ice Service

Total Refrigerated Volume Range	Mid-Point of Total Refrigerated Volume Range	Average Freezer-Volume-to-Total-Refrigerated-Volume	Freezer Volume	Fresh Food Volume	Adjusted Total Volume
(cubic feet)	(cubic feet)		(cubic feet)	(cubic feet)	(cubic feet)
21-23	22.0	0.350	7.7	14.3	26.9
24-26	25.0	0.379	9.5	15.5	31.0
27-30	28.5	0.373	10.6	17.9	35.2

With representative adjusted total volumes established for each size range, the Department was able to determine the annual electricity consumption for baseline products and products with 15 percent and 25 percent less energy consumption. The Department assumed the baseline annual energy consumption for each size range to be equal to the current maximum allowable annual energy consumption.[6] The current maximum allowable annual energy consumption for top-mount refrigerator-freezers without TTD ice service is:

$$TM\ UEC_{max} = 9.8 \bullet Vol_{adj} + 276 \qquad \textbf{Eq. 4.5}$$

where:

$TM\ UEC_{max}$	=	maximum annual (or unit) electricity consumption in kilowatt-hours (kWh) per year for top-mount refrigerator-freezers without TTD ice service, and
Vol_{adj}	=	adjusted total volume in cubic feet.

The current maximum allowable annual energy consumption for side-mount refrigerator-freezers with TTD ice service is:

$$SM\ UEC_{max} = 10.1 \bullet Vol_{adj} + 406 \qquad \textbf{Eq. 4.6}$$

where:

$SM\ UEC_{max}$	=	maximum annual (or unit) electricity consumption in kWh per year for side-mount refrigerator-freezers with TTD ice service, and
Vol_{adj}	=	adjusted total volume in cubic feet.

To arrive at the annual energy consumption values corresponding to the 15 percent less energy use and 25 percent less energy use levels, the Department reduced the baseline energy consumption by 15 percent and 25 percent, respectively. Table 4-17 and Table 4-18 provide the annual energy consumption values for baseline products and products with 15 percent and 25 percent less energy consumption for top-mount and side-mount refrigerator-freezers, respectively.

Table 4-17. Annual Electricity Consumption: Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service

Total Refrigerated Volume Range (cubic feet)	Representative Adjusted Total Volume (cubic feet)	Annual Electricity Consumption (kWh/yr)		
		Baseline	15% less energy	25% less energy
14-17	18.1	453	385	340
18-20	22.2	493	419	370
21-22	25.5	526	447	395

Table 4-18. Annual Electricity Consumption: Refrigerator-Freezers with Side-Mount Freezer and with TTD Ice Service

Total Refrigerated Volume Range (cubic feet)	Representative Adjusted Total Volume (cubic feet)	Annual Electricity Consumption (kWh/yr)		
		Baseline	15% less energy	25% less energy
21-23	26.9	677	576	508
24-26	31.0	719	611	539
27-30	35.2	762	647	571

4.3.1.2 Electricity Prices

When conducting a standards rulemaking, the Department normally uses marginal energy prices for valuing energy savings. Marginal prices are prices that consumers pay (or save) for the last units of energy used (or saved). Marginal prices reflect a change in a consumer's bill (possibly associated with new energy efficiency standards) divided by the corresponding change in the amount of energy the consumer used. However, because the complexity of a marginal price analysis is not warranted for this LCC and PBP analysis, the Department used average electricity prices.

The Department calculated average electricity prices for the residential sector from the Energy Information Administration (EIA)'s *Annual Energy Review (AER) 2003*.[7] Table 4-19 shows the national average residential electricity prices from 2000 to 2003. Electricity prices are provided by EIA in nominal dollars and 2000 dollars. The Department used gross domestic product (GDP) implicit price deflators to convert values into specific years' dollars.[8] Table 4-19 provides the electricity prices in nominal, 2000, 2003, and 2005 dollars.

Table 4-19. Average Residential Retail Price of Electricity, 2000-2003

	Residential Electricity Price (¢/kWh)			
Year	***Nominal $***	***2000$***	***2003$***	***2005$***
2000	8.24	8.24	8.72	8.95
2001	8.62	8.42	8.92	9.15
2002	8.46	8.14	8.60	8.82
2003	8.71	8.24	8.71	8.93

Source: EIA *AER 2003*; conversions to 2003$ and 2005$ done with GDP implicit price deflators.

Because it conducted the LCC and PBP analysis in 2005$, the Department used electricity prices in 2005$. The Department applied projected price trends to the electricity price in 2003 to obtain electricity prices for future years (see Electricity Price Trends, section 3.3.4).

4.3.2 Product Lifetime

The Department estimated the product lifetime from a prior TSD the Department published in 1995 to assess whether amended energy conservation standards were warranted for refrigerator-freezers.[2] The product lifetime from the prior TSD was estimated to be 19 years.

AHAM in their Fact Book provides an estimate of the average length of first ownership of refrigerator-freezers.[9] As stated by AHAM, the length of first ownership does not refer to the average useful product lifetime, which tends to be much higher. In 2001, AHAM reports an average first ownership length of 8.5 years for full size refrigerators. Appliance Magazine provides a range of first ownership lengths based on the expert judgment of their staff.[10] The magazine lists an average first ownership length of 13 years for standard refrigerators (i.e., non-compact) with minimum and maximum lengths of 10 and 16 years, respectively.

For purposes of calculating the LCC, the Department must determine the product's full lifetime operating costs. As a result, the Department uses the product lifetime rather than the length of first ownership. Although the first owner may not be incurring all of the operating costs associated with the appliance, some other consumer is, i.e., the subsequent owner of the appliance.

4.3.3 Discount Rate

The calculation of the LCC uses a discount rate to calculate the present value of future annual electricity costs. To establish the discount rate, the Department used the same discount rate it had developed for another residential product—specifically, residential furnaces and boilers.[11] The Department chose to use only the discount rates that it had developed for the purchase of furnaces and boilers to replace old or failed equipment because most refrigerator-freezers are purchased to replace existing units. For equipment purchased to replace old or failed equipment where cash or some form of credit is used to finance the acquisition, it is appropriate to establish how the purchase affects a consumer's overall household financial situation. For example, even though the purchase might be financed through a dealer loan or other short-term financing vehicle, the purchase is likely to cause the consumer either to incur additional credit card debt or to forego investment in some type of savings-related asset. Cash that was once available either to pay for household expenses or to invest in an asset like the stock market or a savings account now must be earmarked to pay off the equipment purchase, thus causing the consumer to incur additional credit card debt or to lose the opportunity to earn income from assets.

The Department estimated the average household equity and debt portfolio from the 1995 and 1998 Federal Reserve Board's *Survey of Consumer Finance*s (SCF).[12] The Department estimated interest or return rates associated with each type of equity and debt from a variety of sources. Rates for second mortgages and credit cards are from 1998 SCF data. The Department estimated interest rates associated with household certificates of deposit (CDs), treasury bills (T-bills), and corporate bonds as an average of the Federal Reserve Board time-series data covering 1977–2001.[13] Based on relative returns to less-liquid assets, the Department assumed that the interest rate on transactions (checking) accounts averages two percent real. The midpoint of the transactions account distribution is two percent. The Department based the two percent figure on an analysis of returns to money-market accounts and savings accounts, and returns to CD and bond holdings. It estimated the annual return associated with household stock holdings as an average of data published by the Stern Business School covering the 1977–2001 period.[14] The Department estimated mutual fund rates as an average of the Standard and Poor's (S&P) 500 stock rate (67 percent) and the T-bill rate (33 percent).

Table 4-20 summarizes the average shares of household equity and debt based on the above sources and the real, after-tax interest rates associated with each type of equity or debt. The Department assumed a marginal tax rate of 28 percent and Consumer Price Index (CPI) inflation to derive real from nominal values. The weighted-average real, after-tax interest rate across all types of household debt and equity used to purchase replacement furnaces or boilers is 6.7 percent. The Department used a 6.7 percent discount rate for its calculation of the LCC of refrigerator-freezers.

Table 4-20. After-Tax Real Interest or Return Rates for Household Debt and Equity Types

Type	Average Share of Household Debt plus Equity	Mean Rate
Second Mortgage	3.0%	5.9%
Credit Card and installment	9.1%	12.0%
Transaction (checking) accounts	20.0%	2.0%
CD (6-month)	7.9%	2.8%
Savings bonds (Treasury)	1.6%	3.7%
Bonds (Corporate AAA)	8.3%	4.4%
Stocks (S&P 500)	30.2%	9.6%
Mutual funds	19.8%	7.6%
Weighted-average value	**100%**	**6.7%**

Source: DOE 2004 TSD.

4.3.4 Electricity Price Trends

The Department used EIA's *Annual Energy Outlook 2005* (*AEO 2005)* Reference Case[15] residential electricity price forecast to project prices from 2003 to 2035. The Department used a linear extrapolation based on the last ten years (2015–2025) in the forecast to project prices to the end of the analysis period (2035). Figure 4-7 shows the forecasted electricity prices based on a 2003 price of 8.93 ¢/kWh.

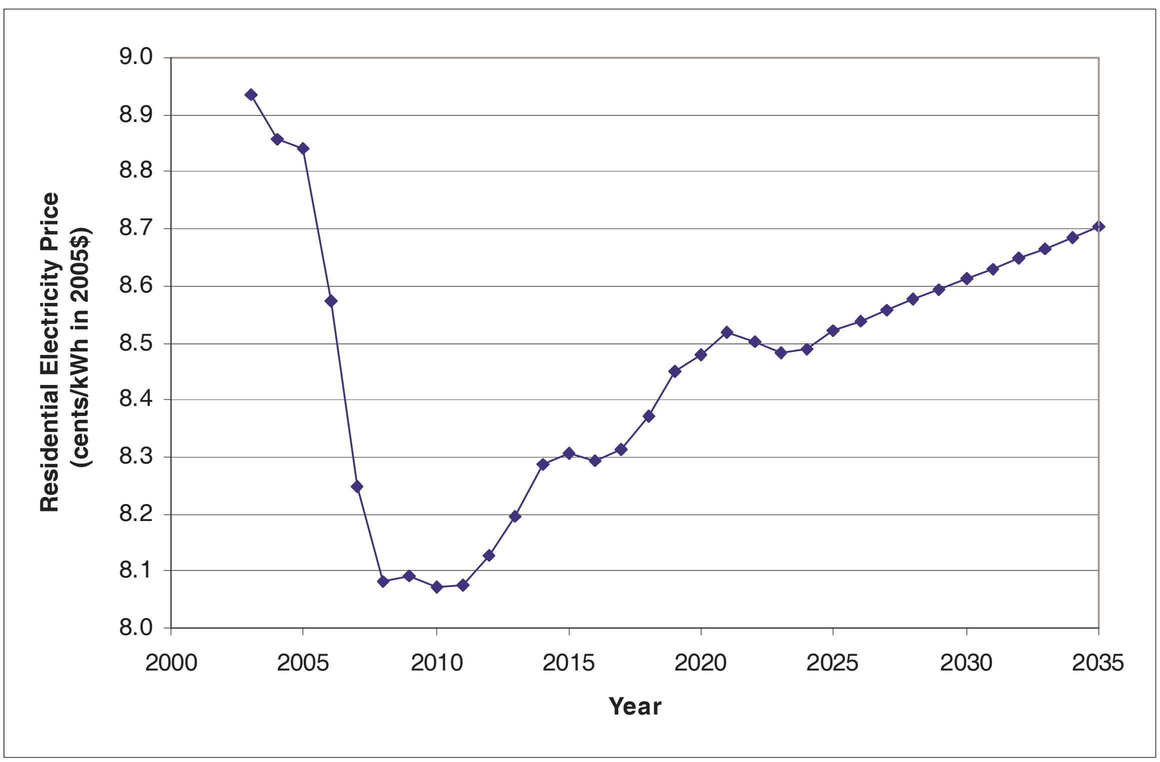

Figure 4-7. Forecasted Electricity Prices

4.4 PAYBACK PERIOD METHODOLOGY

A simple measure of the impact of an energy-efficiency standard is the PBP. PBP relates the increase in total installed costs to the decrease in annual operating costs, where the differences are between the baseline and the more efficient product. In this PBP analysis, total installed costs are equivalent to consumer retail prices and operating costs are equivalent to electricity costs. The Department did not discount costs in determining the PBP.

The PBP is the amount of time (in years) needed to recover, through lower electricity costs (EC), the additional consumer retail price (RP) for the more efficient product. In this analysis, the Department used the electricity costs in the first year. Therefore, the equation has the simple solution:

$$PBP = \frac{\Delta RP}{\Delta EC} \qquad \textbf{Eq. 4.7}$$

where:

PBP = time (in years) needed to recover through lower operating costs,
ΔRP = difference in consumer retail price between the baseline and the more energy efficient product, and
ΔEC = decrease (savings) in annual electricity costs in the year 2010.

4.5 RESULTS OF THE LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

LCC and PBP results are provided for the two product classes that the Department has analyzed: (1) top-mounted freezer without TTD ice service, automatic defrost and (2) side-mounted freezer with TTD ice service, automatic defrost. Results are provided for two standard levels: (1) product with 15 percent less annual energy consumption than the baseline product (i.e., a product meeting current energy conservation standards) and (2) product with 25 percent less annual energy consumption that the baseline product.

The difference in LCC between the baseline product and the more energy-efficient product is the LCC savings. Positive values represent net savings and negative values (in parentheses) represent net costs. The payback period is determined by dividing the increased consumer retail price by the first year's electricity cost savings.

For each of the two product classes analyzed by the Department, the LCC and PBP results include individual tables for the following:

- Consumer Retail Price and Retail Price Increase
- First-Year and Lifetime Electricity Costs and Electricity Cost Savings
- LCC, LCC Savings, and Payback Period

The tables detailing the consumer retail prices and electricity costs are provided to clearly show the components of the LCC and PBP. Table 4-21, Table 4-22, and Table 4-23 provide the results for the top-mount refrigerator-freezer product class. Table 4-24, Table 4-25, and Table 4-26 provide the results for the side-mount refrigerator-freezer product class.

For the 15 percent less energy standard level, a total of twelve results are provided, consisting of a combination of four retail price estimates (three based on minimum, average, and maximum manufacturing costs and one based on the regression analysis) and three size categories. For the 25 percent less energy standard level, a total of nine results are provided for the top-mount product class, consisting of a combination of three retail price estimates (based on minimum, average, and maximum manufacturing costs) and three size categories. For the side-mount product class, only six possible results are provided for the 25 percent less energy standard level, consisting of a combination of three retail price estimates (based on minimum, average, and maximum manufacturing costs) and two size categories.

For the top-mount product class, LCC savings are realized at the 15 percent less energy standard level for 11 of the 12 possible results, with the only exception being the maximum manufacturing-cost-based retail price for the 18–20 cubic foot size category. PBPs of less than half the lifetime of the product (ranging from 2.7 to 9.5 years) are achieved at the 15 percent less energy standard level for 9 of the 12 possible results, with the exceptions being the maximum manufacturing-cost-based retail price for the 18–20 and 21–22 cubic foot size categories as well as the regression-based retail price for the 21-22 cubic foot size category. At the 25 percent less energy standard level, LCC savings are realized for only three of the nine possible results: the minimum manufacturing-cost-based retail price for the 18–20 and 21–22 cubic foot size categories and the average manufacturing-cost-based retail price for the 18–20 cubic foot size category. PBPs of less than half the lifetime of the product (ranging from 3.6 to 7.5 years) at the 25 percent less energy standard level are achieved for only two of the nine possible results: the minimum manufacturing-cost-based retail price for the 18–20 and 21–22 cubic foot size categories.

For the side-mount product class, LCC savings are realized at the 15 percent less energy standard level for 8 of the 12 possible results. LCC savings are not realized for the maximum manufacturing-cost-based retail price at all three size categories as well as the average manufacturing-cost-based retail price for the 27–30 cubic foot size category. PBPs of less than half the lifetime of the product (ranging from 1.1 to 9.6 years) are achieved at the 15 percent less energy standard level for the same eight retail price and size category combinations for which LCC savings are realized. At the 25 percent less energy level, LCC savings are realized for only two of the nine possible results: the minimum manufacturing-cost-based retail price for the 21–23 and 24–26 cubic foot size categories. PBPs of less than half the lifetime (ranging from 0.9 to 4.1 years) of the product are achieved at the 25 percent less energy standard level for the same two retail price and size category combinations for which LCC savings are realized.

Figure 4-8 and Figure 4-9 graphically represent the LCC results for the top-mount and side-mount product classes, respectively. To prevent clutter, LCC results are provided based only on the average manufacturing-cost-based retail price and the regression-analysis-based retail price.

Table 4-21. Consumer Retail Price and Retail Price Increases: Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service

	14-17 cu. ft.				18-20 cu. ft.				21-22 cu. ft.			
	Mfg. Cost-Based			Regress.-Based	Mfg. Cost-Based			Regress.-Based	Mfg. Cost-Based			Regress-Based
	Min.	Avg.	Max.		Min.	Avg.	Max.		Min.	Avg.	Max.	
RETAIL PRICE (2005$)												
Baseline	$329				$386				$457			
15% less energy	$345	$367	$381	$356	$402	$420	$1186	$434	$477	$499	$531	$520
25% less energy	$457	$704	$1047	NA	$422	$494	$668	NA	$537	$613	$735	NA
RETAIL PRICE INCREASE (2005$)												
15% less energy	$16	$38	$52	$28	$16	$35	$800	$49	$20	$42	$74	$63
25% less energy	$128	$376	$718	NA	$36	$108	$282	NA	$80	$157	$278	NA

Table 4-22. First-Year and Lifetime Electricity Costs and Electricity Cost Savings: Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service

FIRST-YEAR ELECTRICITY COSTS (2005$)				**LIFETIME ELECTRICITY COSTS (2005$)**			
Baseline	$37	$40	$42	**Baseline**	$425	$463	$494
15% less energy	$31	$34	$36	**15% less energy**	$362	$394	$420
25% less energy	$27	$30	$32	**25% less energy**	$319	$347	$370
FIRST-YEAR ELECTRICITY COST SAVINGS (2005$)				**LIFETIME ELECTRICITY COST SAVINGS (2005$)**			
15% less energy	$5	$6	$6	**15% less energy**	$64	$69	$74
25% less energy	$9	$10	$11	**25% less energy**	$106	$116	$123

Table 4-23. LCC, LCC Savings, and Payback Periods: Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service

	14-17 cu. ft.				18-20 cu. ft.				21-22 cu. ft.			
	Mfg. Cost-Based			Regress.-Based	Mfg. Cost-Based			Regress.-Based	Mfg. Cost-Based			Regress.-Based
	Min.	Avg.	Min.		Min.	Avg.	Max.		Min.	Avg.	Max.	
LCC (2005$)												
Baseline	$754				$849				$951			
15% less energy	$706	$729	$742	$718	$795	$814	$1579	$828	$897	$919	$951	$940
25% less energy	$776	$1023	$1366	NA	$769	$841	$1015	NA	$907	$984	$1105	NA
LCC SAVINGS (2005$)												
15% less energy	$48	$26	$12	$36	$53	$35	($731)	$21	$54	$32	$0	$11
25% less energy	($22)	($269)	($612)	NA	$80	$8	($166)	NA	$43	($33)	($155)	NA
PAYBACK PERIOD (years)												
15% less energy	2.9	6.9	9.5	5.0	2.7	5.8	133.9	8.1	3.1	6.7	11.6	10.0
25% less energy	14.0	41.1	78.5	NA	3.6	10.9	28.3	NA	7.5	14.7	26.2	NA

Table 4-24. Consumer Retail Price and Retail Price Increases: Refrigerator-Freezers with Side-Mount Freezer and with TTD Ice Service

	21-23 cu. ft.				24-26 cu. ft.				27-30 cu. ft.			
	Mfg. Cost-Based			Regress.-Based	Mfg. Cost-Based			Regress.-Based	Mfg. Cost-Based			Regress.-Based
	Min.	Avg.	Min.		Min.	Avg.	Max.		Min.	Avg.	Max.	
RETAIL PRICE (2005$)												
Baseline	$702				$789				$926			
15% less energy	$712	$756	$892	$750	$799	$824	$999	$855	$1008	$1110	$1136	$1014
25% less energy	$714	$955	$1140	NA	$849	$988	$1399	NA	Insufficient Data			NA
RETAIL PRICE INCREASE (2005$)												
15% less energy	$10	$54	$190	$47	$10	$35	$210	$66	$82	$184	$210	$88
25% less energy	$12	$253	$438	NA	$60	$199	$610	NA	Insufficient Data			NA

Table 4-25. First-Year and Lifetime Electricity Costs and Electricity Cost Savings: Refrigerator-Freezers with Side-Mount Freezer and with TTD Ice Service

FIRST-YEAR ELECTRICITY COSTS (2005$)				**LIFETIME ELECTRICITY COSTS (2005$)**			
Baseline	$55	$58	$61	**Baseline**	$636	$675	$715
15% less energy	$46	$49	$52	**15% less energy**	$540	$574	$608
25% less energy	$41	$44	$46	**25% less energy**	$477	$506	$536
FIRST-YEAR ELECTRICITY COST SAVINGS (2005$)				**LIFETIME ELECTRICITY COST SAVINGS (2005$)**			
15% less energy	$8	$9	$9	**15% less energy**	$95	$101	$107
25% less energy	$14	$15	$15	**25% less energy**	$159	$169	$179

Table 4-26. LCC, LCC Savings, and Payback Periods: Refrigerator-Freezers with Side-Mount Freezer and with TTD Ice Service

	21-23 cu. ft.				24-26 cu. ft.							
	Mfg Cost-Based			Regress-Based	Mfg Cost-Based			Regress-Based	Mfg Cost-Based			Regress-Based
	Min	Avg	Min		Min	Avg			Min	Avg	Max	
LCC (2005$)												
Baseline	$1338				$1463				$1641			
15% less energy	$1253	$1296	$1433	$1290	$1372	$1398	$1572	$1428	$1615	$1717	$1743	$1621
25% less energy	$1191	$1432	$1617	NA	$1355	$1494	$1905	NA	Insufficient Data			NA
LCC SAVINGS (2005$)												
15% less energy	$85	$42	($95)	$48	$91	$66	($109)	$35	$25	($77)	($103)	$19
25% less energy	$147	($94)	($279)	NA	$109	($31)	($441)	NA	Insufficient Data			NA
PAYBACK PERIOD (years)												
15% less energy	1.2	6.6	23.2	5.8	1.1	4.1	24.1	7.6	8.9	19.9	22.8	9.6
25% less energy	0.9	18.5	32.1	NA	4.1	13.7	42.1	NA	Insufficient Data			NA

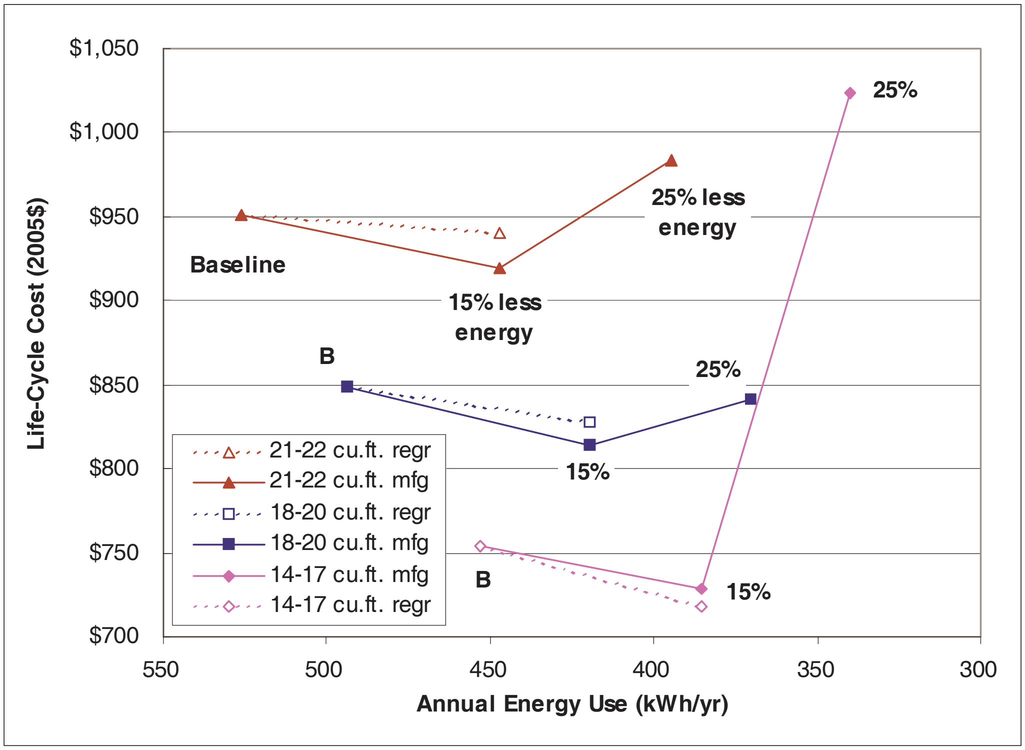

Figure 4-8. Life-Cycle Costs: Top-Mount Refrigerator-Freezers without TTD Ice Service

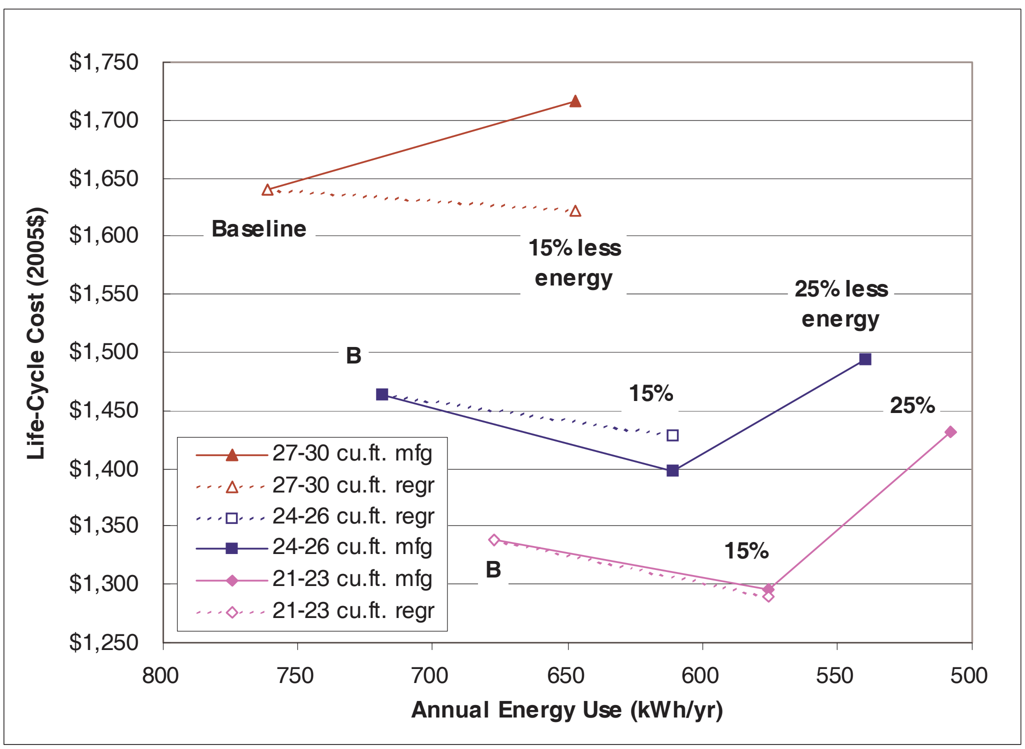

Figure 4-9. Life-Cycle Costs: Side-Mount Refrigerator-Freezers with TTD Ice Service

REFERENCES

1 The NPD Group, Inc., *The NPD Group/NPD Houseworld – POS, Refrigerators, January – December 2004*, 2005. Port Washington, NY.

2 Association of Home Appliance Manufacturers, *Summary Data Tables: Refrigerator-Freezer Data Collection for Cost/Efficiency Information for DOE Petition*, 2005. Information provided by the Association of Home Appliance Manufacturers to the U.S. Department of Energy, May 13, 2005.

3 U.S. Department of Energy, *Technical Support Document: Energy Efficiency Standards for Consumer Products: Refrigerators, Refrigerator-Freezers, & Freezers*, July 1995. Washington, DC. Report No. DOE/EE-0064.

4 Code of Federal Regulations, Appendix A1 to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Electric Refrigerators and Electric Refrigerator-Freezers. 10 CFR Pt. 430, Subpt. B, App. A1.

5 California Energy Commission, *Appliance Database, Refrigerator-Freezers*, 2005. Sacramento, CA. File: comm_refrig_frzrs.zip; Last modified, January 6, 2005. <http://www.energy.ca.gov/appliances/appliance/excel_based_files/refrigerators/>

6 U.S. Department of Energy-Office of Energy Efficiency and Renewable Energy, Energy Conservation Program for Consumer Products: Energy Conservation Standards for Refrigerators, Refrigerator-Freezers and Freezers; Final Rule. *Federal Register*, 1997. 62(81): pp. 23102-23116.

7 U.S. Department of Energy-Energy Information Administration, *Annual Energy Review 2003*, September 2004. Washington DC. Report No. DOE/EIA-0384(2003). Table 8-10, Average Retail Prices of Electricity, 1960-2003.

8 U.S. Government Printing Office, Budget of the United States Government: Historical Tables Fiscal Year 2005, Section 10 – Gross Domestic Product and Implicit Outlay Deflators, Table 10.1 – Goss Domestic Product and Deflators Used in the Historical Tables: 1940–2009, 2005. Washington, DC. GPO Access: <http://www.gpoaccess.gov/usbudget/fy05/hist.html>

9 Association of Home Appliance Manufacturers, *2003 Fact Book*, 2003. Washington, DC. Table 11.

10 "The Life Expectancy/Replacement Picture," *Appliance Magazine*, September 2004. p. P-5.

11 U.S. Department of Energy-Office of Energy Efficiency and Renewable Energy, *Technical Support Document: Energy Efficiency Program for Consumer Products: Energy Conservation Standards for Residential Furnaces and Boilers*, September 2004. Washington, DC.

[12] The Federal Reserve Board, *1998 Survey of Consumer Finances,* 1998. <http://www.federalreserve.gov/pubs/oss/oss2/98/scf98home.html#summary>

[13] The Federal Research Board, Federal Reserve Statistical Interest Rates, H.15 Historical Data, 2000.

[14] Damodaran Online Data Page, *Historical Returns on Stocks, Bonds and Bills-United States.* (Last accessed October 9, 2002), <http://pages.stern.nyu.edu/~adamodar/>

[15] U.S. Department of Energy-Energy Information Administration, *Annual Energy Outlook 2005*, February, 2005. Washington, DC. Report No. DOE/EIA-0383(2005).

CHAPTER 5. NATIONAL IMPACT ANALYSIS

This chapter describes the national impact analysis, consisting of the determination of national energy savings (NES) and national net present value (NPV) from an energy conservation (or efficiency) standard that would require refrigerator-freezers to use 15 percent less energy than current baseline models. For purposes of this analysis, the Department assumed the effective date of such a standard would be the year 2010. The Department assumed the energy consumption of baseline products to equal the maximum energy consumption allowed by current energy conservation standards. Refrigerator-freezers with 15 percent less energy consumption correspond to products meeting current Energy Star requirements. For the purposes of this analysis, the Department analyzed the NES and NPV of amended energy conservation standards for the following two product classes of refrigerators, refrigerator-freezers, and freezers: (1) top-mounted freezer without through-the-door (TTD) ice service, automatic defrost, and (2) side-mounted freezer with TTD ice service, automatic defrost.

5.1 NATIONAL ENERGY SAVINGS CALCULATION

Figure 5-1 illustrates the inputs, intermediate values, and outputs of the NES calculation. The NES is the difference between the national energy consumption in the base case (i.e., the case without amended energy conservation standards) and the standards case (i.e., the case with amended energy conservation standards). The Department developed a spreadsheet model to calculate the NES from refrigerator-freezer standards for the two product classes of interest to this analysis. The spreadsheet model calculated the stock of refrigerator-freezers for these two product classes in any given year by adding up the shipments of refrigerator-freezers in that year plus the preceding 18 years (based on a refrigerator-freezer lifetime of 19 years). The average unit (or annual) electricity consumption (UEC) of the refrigerator-freezer stock was calculated from the average UEC of shipments in each of the relevant years. This calculation was performed separately for the base case and the standards case. The total number of refrigerator-freezers in the stock was then multiplied by the average UEC to calculate annual site electricity consumption. The site-to-source conversion factor for that year was then used to calculate source energy consumption in primary quadrillion (10^{15}) British thermal units (quads). This was calculated for the base case and the standards case and the difference was taken to determine annual energy savings from a standard. The energy savings were summed for all of the years of the analysis period (2010–2035) to determine the cumulative national energy savings.

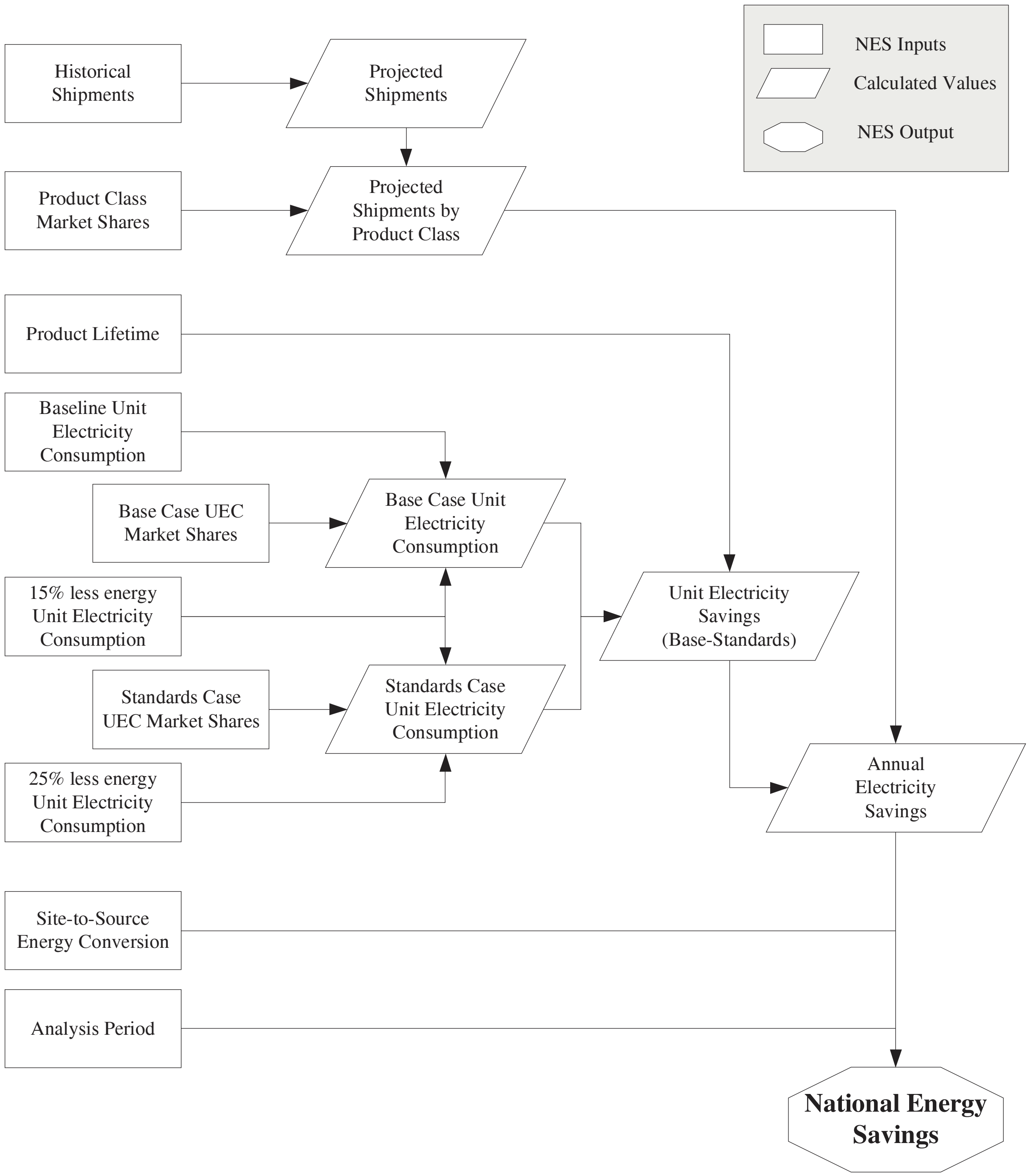

Figure 5-1. Flow Diagram of National Energy Savings Calculation

5.2 NET PRESENT VALUE CALCULATION

Figure 5-2 illustrates the inputs, intermediate values, and outputs of the NPV calculation. The NPV is the difference between the sum of national total installed costs and operating costs in the base case and the sum of national total installed costs and operating costs in the standards case. For the purposes of this analysis, the total installed cost consists only of the consumer retail price of the refrigerator-freezer and the operating cost consists only of the electricity cost. A positive NPV occurs when the present value of electricity cost savings exceeds the present value of increased refrigerator-freezer retail prices associated with the standard. The Department determined the NPV of standards with the same spreadsheet model used to calculate the NES. The electricity savings in each year were multiplied by that year's electricity price to determine annual electricity cost savings. For each year, the spreadsheet also calculated the weighted-average consumer retail price of refrigerator-freezers in the base case and standards case, and took the difference to determine the incremental retail price per unit. To determine the annual incremental cost of efficiency, this incremental retail price was multiplied by the number of units shipped in that year. This incremental cost was subtracted from the annual electricity cost savings to determine annual net savings or costs. A discount factor was applied to each year's annual savings or costs to determine the net present value of the savings or costs. These savings or costs were then summed across all of the years of the analysis to give the total NPV of standards.

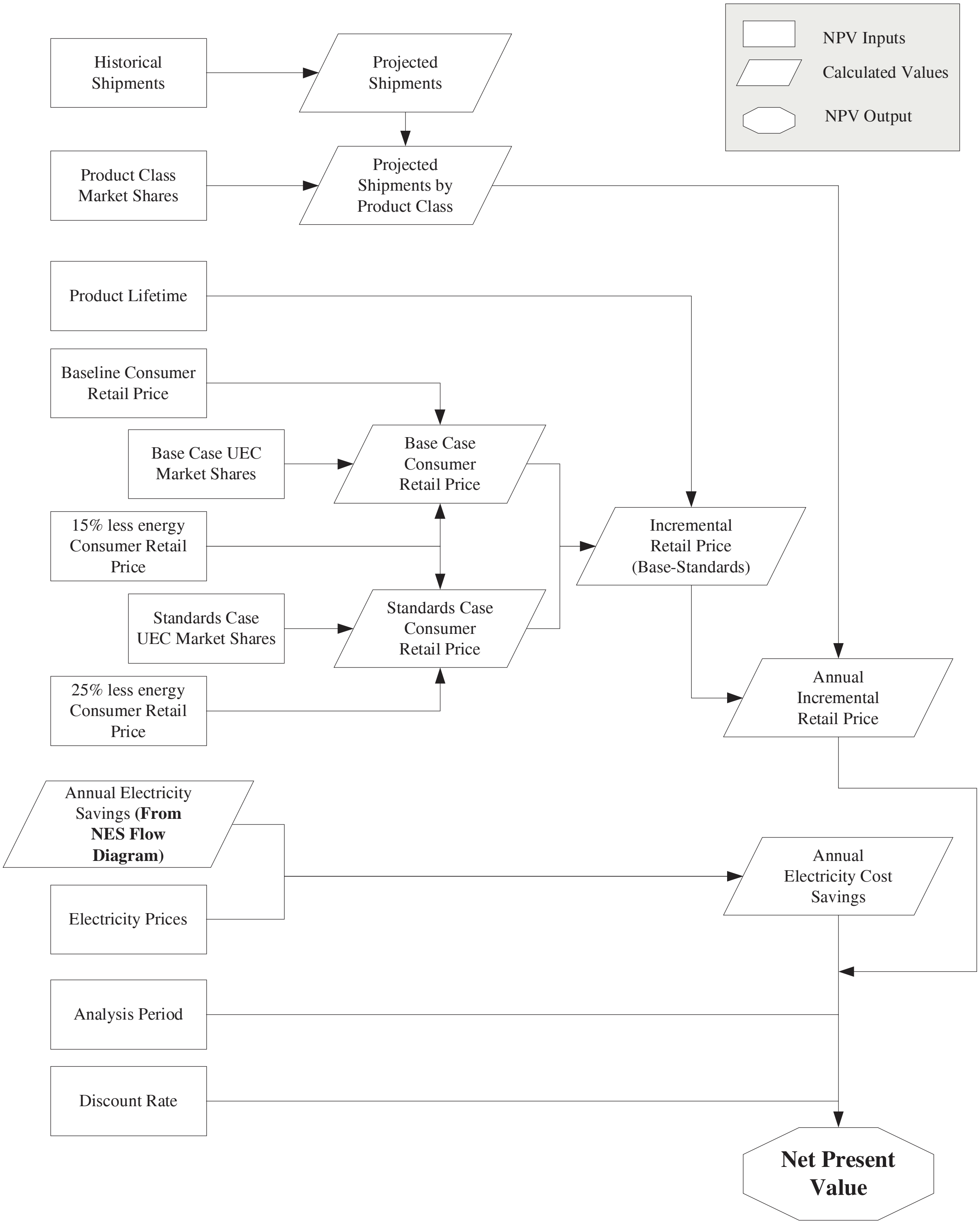

Figure 5-2. Flow Diagram of Net Present Value Calculation

5.3 INPUTS TO THE NES AND NPV CALCULATIONS

The following sections discuss and document the inputs to the calculation of the NES and NPV.

5.3.1 Shipments

5.3.1.1 Historical Shipments

The Department obtained historical refrigerator-freezer shipment data from the Association of Home Appliance Manufacturers (AHAM).[1] Table 5-1 shows historical refrigerator-freezer shipments from 1982 through 2004.

Table 5-1. Historical Refrigerator-Freezer Shipments

Year	Shipments (million)
1982	4.36
1983	5.34
1984	5.88
1985	6.00
1986	6.41
1987	6.75
1988	6.73
1989	6.45
1990	6.46
1991	6.41
1992	6.72
1993	7.05
1994	7.59
1995	7.65
1996	7.98
1997	7.92
1998	8.77
1999	9.10
2000	9.22
2001	9.31
2002	9.74
2003	10.02
2004	10.92

Source: AHAM.

5.3.1.2 Projected Shipments

The Department estimated future shipments from a linear extrapolation of the historical shipments growth trend in the years 1995 through 2004. Figure 5-3 shows the linear extrapolation and Table 5-2 shows projected refrigerator-freezer shipments for 2005 through 2035.

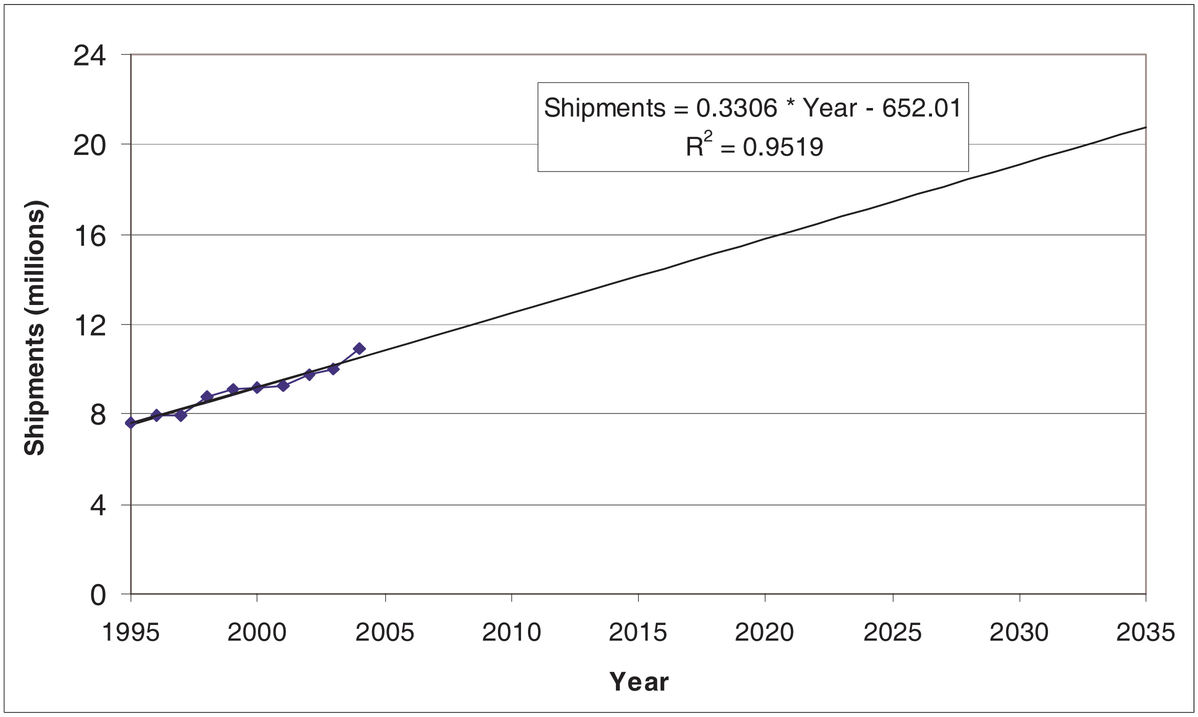

Figure 5-3. Projection of Refrigerator-Freezer Shipments to 2035

Table 5-2. Projected Refrigerator-Freezer Shipments

Year	Shipments (million)
2005	10.84
2006	11.17
2007	11.50
2008	11.83
2009	12.17
2010	12.50
2011	12.83
2012	13.16
2013	13.49
2014	13.82
2015	14.15
2016	14.48
2017	14.81
2018	15.14
2019	15.47
2020	15.80
2021	16.13
2022	16.46
2023	16.79
2024	17.12
2025	17.46
2026	17.79
2027	18.12
2028	18.45
2029	18.78
2030	19.11
2031	19.44
2032	19.77
2033	20.10
2034	20.43
2035	20.76

5.3.1.3 Product Class Market Shares and Project Shipments by Product Class

The Department used AHAM data on the market share of different refrigerator-freezer types to estimate the fraction of all refrigerator-freezer shipments that fall into the two product classes considered for this analysis (i.e., top-mount refrigerator-freezers without TTD ice service and side-mount refrigerator-freezers with TTD ice service), as well as the capacity size ranges included in this analysis.[1] Table 5-3 shows the AHAM market share data for top- or bottom-mounted refrigerator-freezers as well as for side-mount refrigerator-freezers.

Table 5-3. Market Share of Refrigerator-Freezer Product Classes

Year	Top- or Bottom-Mount Freezer (percent)	Side-Mount Freezer (percent)
1998	69.27	29.92
1999	68.82	30.77
2000	68.33	31.31
2001	67.53	32.08
2002	66.59	32.78
2003	63.70	34.51
2004	63.41	35.09

Source: AHAM.

The Department estimated future market shares for these two categories of refrigerator-freezers by performing a linear extrapolation of the market shares from 1998 to 2004. The third and fourth columns of Table 5-4 show the results of this extrapolation.

Based on data from The NPD Group, the Department estimated that top-mount refrigerator-freezers without TTD ice service in the size category range of 14 to 21 cubic feet[d] comprise 81.2 percent of total top- and bottom-mount refrigerators.[2] It also estimated that side-mount refrigerator-freezers with TTD ice service in the size category range of 21 to 30 cubic feet comprise 98.4 percent of total side-mount refrigerator-freezer shipments.[2] The Department applied these multipliers to the refrigerator-freezer shipments to calculate shipments of only those product classes covered by this analysis. The last two columns of Table 5-4 show the refrigerator-freezer shipments used in the analysis.

[d] Size category is based on cubic feet of total refrigerated volume (fresh food volume plus freezer volume).

Table 5-4. Refrigerator-Freezer Shipments Used in the Analysis

Year	Historical + Projected (million)	Percent Top- or Bottom-Mount Freezer	Percent Side-Mount Freezer	Shipments of included Top-Mount Freezer (million)	Shipments of included Side-Mount Freezer (million)
1995	7.65	73.18%	26.82%	4.55	2.02
1996	7.98	72.12%	27.88%	4.67	2.19
1997	7.92	71.07%	28.88%	4.57	2.25
1998	8.77	69.27%	29.92%	4.93	2.58
1999	9.10	68.82%	30.77%	5.09	2.76
2000	9.22	68.33%	31.31%	5.12	2.84
2001	9.31	67.53%	32.08%	5.10	2.94
2002	9.74	66.59%	32.78%	5.27	3.14
2003	10.02	63.70%	34.51%	5.18	3.40
2004	10.92	63.41%	35.09%	5.62	3.77
2005	10.84	62.62%	35.87%	5.52	3.83
2006	11.17	61.57%	36.74%	5.59	4.04
2007	11.50	60.51%	37.62%	5.65	4.26
2008	11.83	59.45%	38.49%	5.72	4.48
2009	12.17	58.40%	39.36%	5.77	4.71
2010	12.50	57.34%	40.24%	5.82	4.95
2011	12.83	56.29%	41.11%	5.86	5.19
2012	13.16	55.23%	41.98%	5.90	5.44
2013	13.49	54.18%	42.86%	5.94	5.69
2014	13.82	53.12%	43.73%	5.96	5.95
2015	14.15	52.06%	44.60%	5.98	6.21
2016	14.48	51.01%	45.48%	6.00	6.48
2017	14.81	49.95%	46.35%	6.01	6.76
2018	15.14	48.90%	47.22%	6.01	7.04
2019	15.47	47.84%	48.10%	6.01	7.32
2020	15.80	46.79%	48.97%	6.01	7.62
2021	16.13	45.73%	49.85%	5.99	7.91
2022	16.46	44.67%	50.72%	5.97	8.22
2023	16.79	43.62%	51.59%	5.95	8.53
2024	17.12	42.56%	52.47%	5.92	8.84
2025	17.46	41.51%	53.34%	5.89	9.16
2026	17.79	40.45%	54.21%	5.84	9.49
2027	18.12	39.40%	55.09%	5.80	9.82
2028	18.45	38.34%	55.96%	5.74	10.16
2029	18.78	37.28%	56.83%	5.69	10.50
2030	19.11	36.23%	57.71%	5.62	10.85
2031	19.44	35.17%	58.58%	5.55	11.21
2032	19.77	34.12%	59.46%	5.48	11.57
2033	20.10	33.06%	60.33%	5.40	11.93
2034	20.43	32.01%	61.20%	5.31	12.31
2035	20.76	30.95%	62.08%	5.22	12.68

Sources: Columns 1–3: AHAM; Columns 4–5: The NPD Group/NPD Houseworld – POS.

5.3.2 Unit Electricity Consumption and Consumer Retail Prices

5.3.2.1 Weighted-Average Unit Electricity Consumption and Per-Unit Consumer Retail Price for Baseline, 15 percent less energy, and 25 percent less energy Products

For each of the two product classes, top-mount refrigerator-freezers and side-mount refrigerator-freezers, the Department calculated a representative weighted-average UEC and a representative weighted-average per-unit consumer retail price for a baseline refrigerator-freezer, for a refrigerator-freezer that consumes 15 percent less energy, and for a refrigerator-freezer that consumes 25 percent less energy. The UEC and retail price data are shown in Table 5-5 and Table 5-6 for top-mount and side-mount units, respectively. The Department used data from The NPD Group to estimate the percent of shipments allocated to each size category to arrive at weighted-average UEC and retail price values.[1] The UECs are from the life-cycle cost (LCC) and payback period (PBP) analysis. The retail prices are also from the LCC and PBP analysis and are based on the average manufacturing-cost-based retail prices as well as the regression analysis-based retail prices.

Table 5-5. Weighted-Average UECs and Retail Prices: Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service

Size Category (cubic feet)	Percent of shipments	UEC (kWh/yr)			Retail Price (2005$)			
						Avg. Mfg. Cost-Based		Regress.
		Baseline	15% less energy	25% less energy	Baseline	15% less energy	25% less energy	15% less energy
14-17	21.9%	453	385	340	$329	$367	$704	$356
18-20	43.9%	493	419	370	$386	$420	$494	$434
21-22	26.3%	526	447	395	$457	$499	$613	$520
Weighted-Avg. Value		**493**	**419**	**370**	**$392**	**$430**	**$578**	**$440**

Sources: Percent of Shipments: The NPD Group/NPD Houseworld – POS ; UEC: Table 4-17, LCC and PBP Analysis; Retail Price: Table 4-21, LCC and PBP Analysis.

Table 5-6. Weighted-Average UECs and Retail Prices: Refrigerator-Freezers with Side-Mount Freezer and with TTD Ice Service

Size Category (cubic feet)	Percent of shipments	UEC (kWh/yr)			Retail Price (2005$)			
						Avg. Mfg. Cost-Based		Regress.
		Baseline	15% less energy	25% less energy	Baseline	15% less energy	25% less energy	15% less energy
21-23	25.1%	677	575	508	$702	$756	$955	$750
24-26	74.2%	719	611	539	$789	$824	$988	$855
27-30	0.3%	762	648	572	$926	$1,110	$1,209*	$1014
Weighted-Avg. Value		**709**	**602**	**531**	**$767**	**$808**	**$980**	**$829**

* Due to insufficient data, the value here is an approximation based on the price differential for the 25% less energy model for the two smaller size categories.

Sources: Percent of Shipments: The NPD Group/NPD Houseworld – POS ; UEC: Table 4-18, LCC and PBP Analysis; Retail Price: Table 4-24, LCC and PBP Analysis.

5.3.2.2 Base Case and Standards Case Market Shares

The UECs and consumer retail prices associated with the base case and standards case are dependent on the market shares of baseline, 15 percent less energy, and 25 percent less energy products.

Base Case Market Shares. The Department based the market share of baseline and current Energy Star (i.e., 15 percent less energy) products for top-mount and side-mount refrigerator-freezers in the years 2002–2004 on data provided by AHAM (Table 5-7).[1] Note that the market share of products with 25 percent less energy consumption for the years 2002–2004 is negligible. Also note that market share data were not made available for the first year (2001) in which the last set of refrigerator-freezer energy conservation standards became effective.

Table 5-7. Market Share of Baseline and Current Energy Star Refrigerator-Freezers

Year	Top-Mount Refrigerator-Freezers		Side-Mount Refrigerator-Freezers	
	Baseline Market Share	15% less energy market share	Baseline Market Share	15% less energy market share
2002	86%	14%	54%	46%
2003	79%	21%	49%	51%
2004	78%	22%	51%	49%

Source: AHAM.

For years after 2004, because the market share of current Energy Star products did not appreciably change from 2003 to 2004, the Department assumed for the base case that the market share of baseline and current Energy Star products remained essentially unchanged from their 2004 levels. From 2005 to 2035, the Department assumed that the market share of baseline and current Energy Star refrigerator-freezers stay fixed at 78 percent and 22 percent, respectively. For side-mount refrigerator-freezers, the Department assumed that the market share of baseline and current Energy Star products remained at 50 percent each from 2005 to 2035.

Standards Case Market Shares. For a new amended energy conservation standard set at current Energy Star levels (i.e., 15 less energy consumption), the market share of the current Energy Star product (which would become the new baseline level) and any future Energy Star product can have a significant impact on the NES and NPV due to the new standard. Because it is difficult to forecast the market share of products once a new standard becomes effective, the Department analyzed the following two market share scenarios: (1) a No Future Energy Star scenario where 100 percent of the market is assumed to be at the new standard level (which is equivalent to the current Energy Star level), and (2) a Current Energy Star scenario where market shares of current and future Energy Star are assumed to be equivalent to the market shares of current baseline and current Energy Star products. Under the Current Energy Star scenario, the future Energy Star level is assumed to have 25 percent less energy consumption than current baseline products.

Table 5-8 shows the standards case market shares for top-mount refrigerators under the No Future Energy Star and Current Energy Star market share scenarios. Under the Current Energy Star scenario, after the standard becomes effective in 2010, the market share of current and future Energy Star products in the years 2011–2013 are assumed to be equivalent to the market share of current baseline and current Energy Star products in the years 2002–2004. For subsequent years out to 2035, the market shares are equivalent to what is assumed in the base case for current baseline and current Energy Star products (i.e., 78 percent and 22 percent, respectively). Because data were not available to show the market share of current Energy Star products in 2001, the Department assumed that the market shares of current and future Energy Star products in 2010 are 90 percent and 10 percent, respectively.

Table 5-8. Standards Case Market Share Scenarios: Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service

Year	No Future Energy Star Scenario			Current Energy Star Scenario		
	Current Baseline	Current Energy Star (15% less energy)	Future Energy Star (25% less energy)	Current Baseline	Current Energy Star (15% less energy)	Future Energy Star (25% less energy)
2002	86%	14%	0%	86%	14%	0%
2003	79%	21%	0%	79%	21%	0%
2004	78%	22%	0%	78%	22%	0%
2005	78%	22%	0%	78%	22%	0%
2006	78%	22%	0%	78%	22%	0%
2007	78%	22%	0%	78%	22%	0%
2008	78%	22%	0%	78%	22%	0%
2009	78%	22%	0%	78%	22%	0%
2010	0%	100%	0%	0%	90%	10%
2011	0%	100%	0%	0%	86%	14%
2012	0%	100%	0%	0%	79%	21%
2013	0%	100%	0%	0%	78%	22%
2014	0%	100%	0%	0%	78%	22%
2015	0%	100%	0%	0%	78%	22%
2016	0%	100%	0%	0%	78%	22%
2017	0%	100%	0%	0%	78%	22%
2018	0%	100%	0%	0%	78%	22%
2019	0%	100%	0%	0%	78%	22%
2020	0%	100%	0%	0%	78%	22%
2021	0%	100%	0%	0%	78%	22%
2022	0%	100%	0%	0%	78%	22%
2023	0%	100%	0%	0%	78%	22%
2024	0%	100%	0%	0%	78%	22%
2025	0%	100%	0%	0%	78%	22%
2026	0%	100%	0%	0%	78%	22%
2027	0%	100%	0%	0%	78%	22%
2028	0%	100%	0%	0%	78%	22%
2029	0%	100%	0%	0%	78%	22%
2030	0%	100%	0%	0%	78%	22%
2031	0%	100%	0%	0%	78%	22%
2032	0%	100%	0%	0%	78%	22%
2033	0%	100%	0%	0%	78%	22%
2034	0%	100%	0%	0%	78%	22%
2035	0%	100%	0%	0%	78%	22%

Table 5-9 shows the standards case market shares for side-mount refrigerators under the No Future Energy Star and Current Energy Star market share scenarios. Under the Current Energy Star scenario, after the standard becomes effective in 2010, the market share of current and future Energy Star products in the years 2011–2013 would be equivalent to the market share of current baseline and current Energy Star products in the years 2002–2004. For subsequent years out to 2035, the market shares are equivalent to what is assumed in the base case for current baseline and current Energy Star products (i.e., 50 percent). Because data were not available to show the market share of current Energy Star products in 2001, the Department assumed that the market shares of current and future Energy Star products in 2010 are 75 percent and 25 percent, respectively.

Table 5-9. Standards Case Market Share Scenarios: Refrigerator-Freezers with Side-Mount Freezer and with TTD Ice Service

Year	No Future Energy Star Scenario			Current Energy Star Scenario		
	Current Baseline	Current Energy Star (15% less energy)	Future Energy Star (25% less energy)	Current Baseline	Current Energy Star (15% less energy)	Future Energy Star (25% less energy)
2002	54%	46%	0%	54%	46%	0%
2003	49%	51%	0%	49%	51%	0%
2004	51%	49%	0%	51%	49%	0%
2005	50%	50%	0%	50%	50%	0%
2006	50%	50%	0%	50%	50%	0%
2007	50%	50%	0%	50%	50%	0%
2008	50%	50%	0%	50%	50%	0%
2009	50%	50%	0%	50%	50%	0%
2010	0%	100%	0%	0%	75%	25%
2011	0%	100%	0%	0%	54%	46%
2012	0%	100%	0%	0%	49%	51%
2013	0%	100%	0%	0%	51%	49%
2014	0%	100%	0%	0%	50%	50%
2015	0%	100%	0%	0%	50%	50%
2016	0%	100%	0%	0%	50%	50%
2017	0%	100%	0%	0%	50%	50%
2018	0%	100%	0%	0%	50%	50%
2019	0%	100%	0%	0%	50%	50%
2020	0%	100%	0%	0%	50%	50%
2021	0%	100%	0%	0%	50%	50%
2022	0%	100%	0%	0%	50%	50%
2023	0%	100%	0%	0%	50%	50%
2024	0%	100%	0%	0%	50%	50%
2025	0%	100%	0%	0%	50%	50%
2026	0%	100%	0%	0%	50%	50%
2027	0%	100%	0%	0%	50%	50%
2028	0%	100%	0%	0%	50%	50%
2029	0%	100%	0%	0%	50%	50%
2030	0%	100%	0%	0%	50%	50%
2031	0%	100%	0%	0%	50%	50%
2032	0%	100%	0%	0%	50%	50%
2033	0%	100%	0%	0%	50%	50%
2034	0%	100%	0%	0%	50%	50%
2035	0%	100%	0%	0%	50%	50%

5.3.2.3 Base Case and Standards Case Unit Electricity Consumption and Consumer Retail Prices

Based on the weighted-average UEC and per-unit consumer retail price data in Table 5-5 and Table 5-6, and the base case and standards case market share data in Table 5-7, Table 5-8, and Table 5-9, the Department determined the average annual UEC and consumer retail price of new product shipments corresponding to each year of the base case and standards case forecast.

Base Case and Standards Case Unit Energy Consumption. Table 5-10 and Figure 5-4 show the average UECs of new product shipments in the base case and standards case for the top-mount refrigerator-freezer product class. Table 5-11 and Figure 5-5 show the average UECs of new product shipments in the base case and standards case for the side-mount refrigerator-freezer product class. Under the standards case there are two scenarios considered; the No Future Energy Star and Current Energy Star scenarios.

Table 5-10. Base Case and Standards Case Average UECs for New Product Shipments: Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service

Year	Base Case UEC (kWh/yr)	Standards Case UEC	
		No Future Energy Star Scenario (kWh/yr)	Current Energy Star Scenario (kWh/yr)
2002	483	483	483
2003	477	477	477
2004	477	477	477
2005	477	477	477
2006	477	477	477
2007	477	477	477
2008	477	477	477
2009	477	477	477
2010	477	419	414
2011	477	419	412
2012	477	419	409
2013	477	419	408
2014	477	419	408
2015	477	419	408
2016	477	419	408
2017	477	419	408
2018	477	419	408
2019	477	419	408
2020	477	419	408
2021	477	419	408
2022	477	419	408
2023	477	419	408
2024	477	419	408
2025	477	419	408
2026	477	419	408
2027	477	419	408
2028	477	419	408
2029	477	419	408
2030	477	419	408
2031	477	419	408
2032	477	419	408
2033	477	419	408
2034	477	419	408
2035	477	419	408

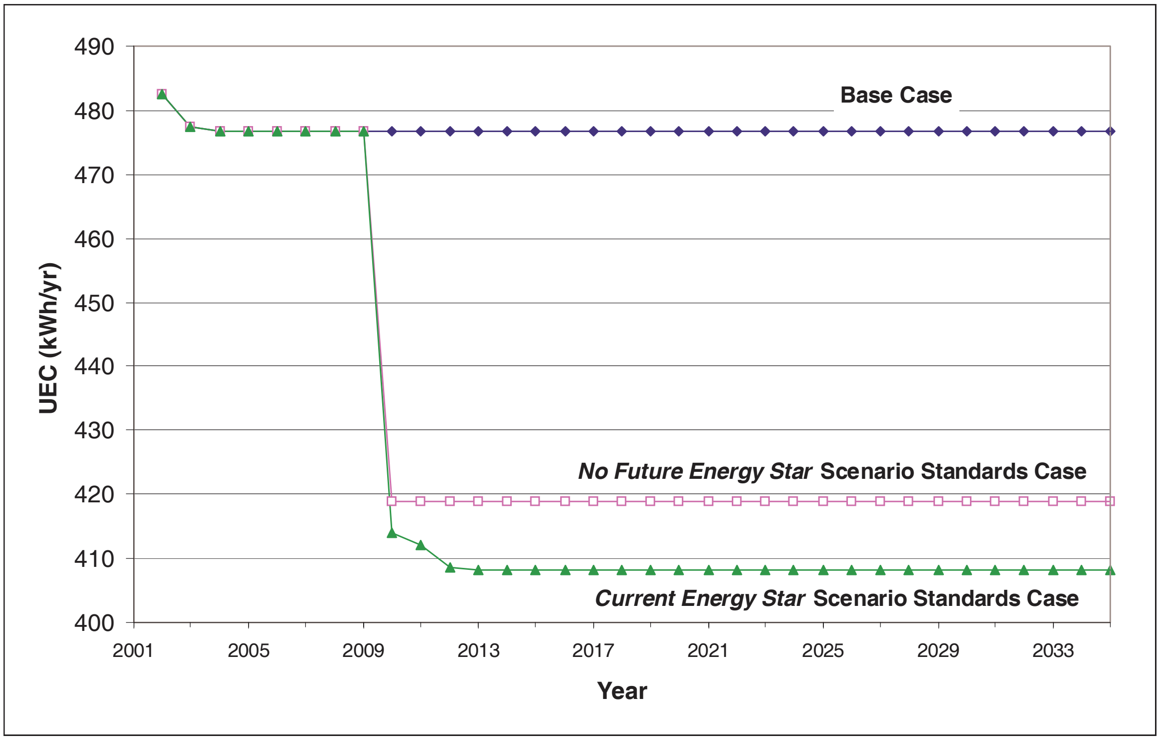

Figure 5-4. Base Case and Standards Case Average UECs for New Product Shipments: Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service

Table 5-11. Base Case and Standards Case Average UECs for New Product Shipments: Refrigerator-Freezers with Side-Mount Freezer and with TTD Ice Service

Year	Base Case UEC (kWh/yr)	Standards Case UEC: No Future Energy Star Scenario (kWh/yr)	Standards Case UEC: Current Energy Star Scenario (kWh/yr)
2002	660	660	660
2003	654	654	654
2004	656	656	656
2005	655	655	655
2006	655	655	655
2007	655	655	655
2008	655	655	655
2009	655	655	655
2010	655	602	585
2011	655	602	570
2012	655	602	566
2013	655	602	568
2014	655	602	567
2015	655	602	567
2016	655	602	567
2017	655	602	567
2018	655	602	567
2019	655	602	567
2020	655	602	567
2021	655	602	567
2022	655	602	567
2023	655	602	567
2024	655	602	567
2025	655	602	567
2026	655	602	567
2027	655	602	567
2028	655	602	567
2029	655	602	567
2030	655	602	567
2031	655	602	567
2032	655	602	567
2033	655	602	567
2034	655	602	567
2035	655	602	567

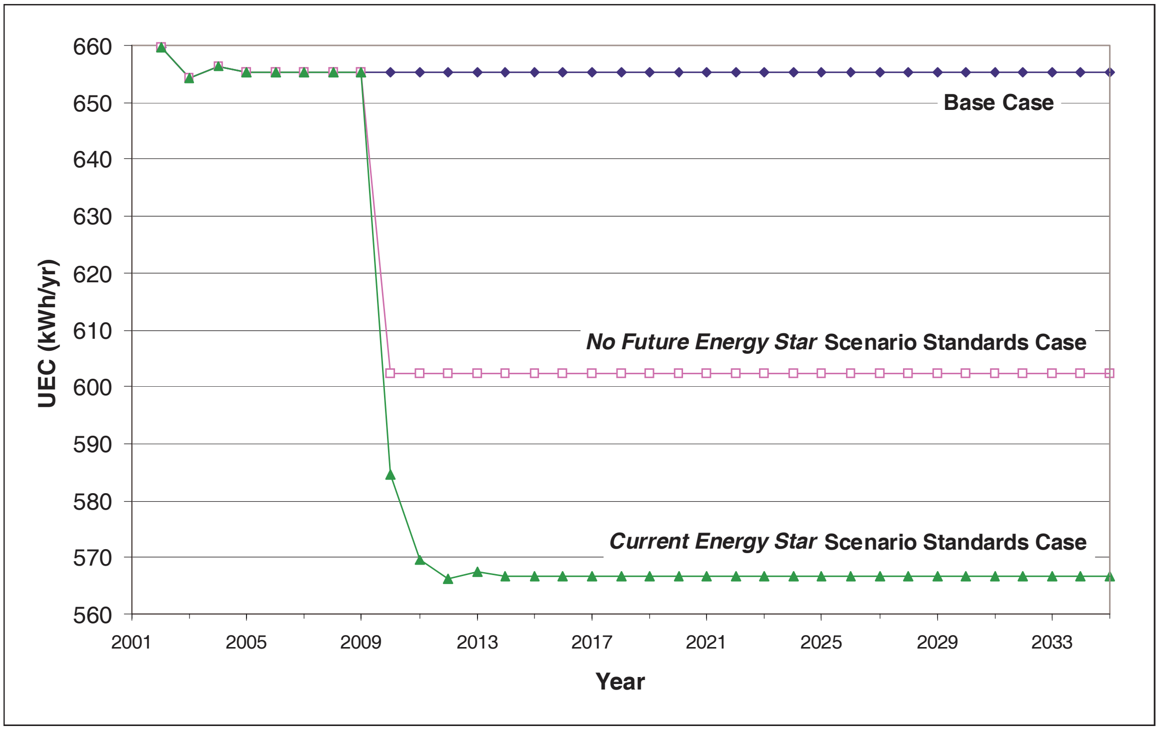

Figure 5-5. Base Case and Standards Case Average UECs for New Product Shipments: Refrigerator-Freezers with Side-Mount Freezer and with TTD Ice Service

Base Case and Standards Case Unit Consumer Retail Prices. Table 5-12 and Figure 5-6 show the average per-unit consumer retail prices of new product shipments in the base case and standards case for the top-mount refrigerator-freezer product class. Table 5-13 and Figure 5-7 show the average per-unit consumer retail prices of new product shipments in the base case and standards case for the side-mount refrigerator-freezer product class. Under the standards case there are two scenarios considered; the No Future Energy Star and Current Energy Star scenarios. For the No Future Energy Star scenario, retail prices are based on the two sets of price estimates; average manufacturing cost-based and regression analysis-based. As noted earlier, the Current Energy Star scenario is composed of products with 15 percent less energy consumption and 25 percent less energy consumption. Because the Department could not use the regression analysis to generate prices for products with 25 percent less energy consumption, retail prices under the Current Energy Star scenario are based only on manufacturing costs.

Table 5-12. Base Case and Standards Case Average Per-Unit Consumer Retail Prices for New Product Shipments: Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service

Year	Average Mfg. Cost-Based Retail Price (2005$)			Regression-Based Retail Price (2005$)	
		Standards Case			Standards Case
	Base Case	No Future Energy Star Scenario	Current Energy Star Scenario	Base Case	No Future Energy Star Scenario
2002	$398	$398	$398	$399	$399
2003	$400	$400	$400	$402	$402
2004	$401	$401	$401	$403	$403
2005	$401	$401	$401	$403	$403
2006	$401	$401	$401	$403	$403
2007	$401	$401	$401	$403	$403
2008	$401	$401	$401	$403	$403
2009	$401	$401	$401	$403	$403
2010	$401	$430	$445	$403	$440
2011	$401	$430	$451	$403	$440
2012	$401	$430	$461	$403	$440
2013	$401	$430	$463	$403	$440
2014	$401	$430	$463	$403	$440
2015	$401	$430	$463	$403	$440
2016	$401	$430	$463	$403	$440
2017	$401	$430	$463	$403	$440
2018	$401	$430	$463	$403	$440
2019	$401	$430	$463	$403	$440
2020	$401	$430	$463	$403	$440
2021	$401	$430	$463	$403	$440
2022	$401	$430	$463	$403	$440
2023	$401	$430	$463	$403	$440
2024	$401	$430	$463	$403	$440
2025	$401	$430	$463	$403	$440
2026	$401	$430	$463	$403	$440
2027	$401	$430	$463	$403	$440
2028	$401	$430	$463	$403	$440
2029	$401	$430	$463	$403	$440
2030	$401	$430	$463	$403	$440
2031	$401	$430	$463	$403	$440
2032	$401	$430	$463	$403	$440
2033	$401	$430	$463	$403	$440
2034	$401	$430	$463	$403	$440
2035	$401	$430	$463	$403	$440

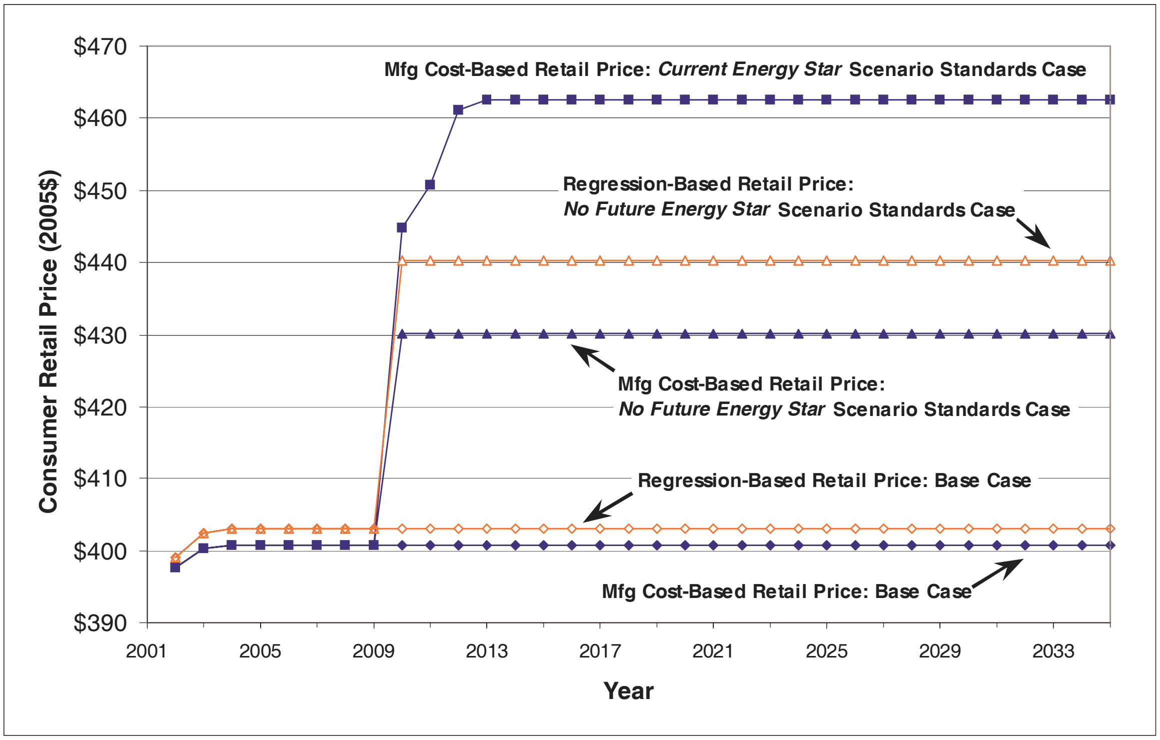

Figure 5-6. Base Case and Standards Case Average Per-Unit Consumer Retail Prices for New Product Shipments: Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service

Table 5-13. Base Case and Standards Case Average Per-Unit Consumer Retail Prices for New Product Shipments: Refrigerator-Freezers with Side-Mount Freezer and with TTD Ice Service

Year	Average Mfg. Cost-Based Retail Price (2005$)			Regression-Based Retail Price (2005$)	
		Standards Case			Standards Case
	Base Case	No Future Energy Star Scenario	Current Energy Star Scenario	Base Case	No Future Energy Star Scenario
2002	$786	$786	$786	$796	$796
2003	$788	$788	$788	$799	$799
2004	$787	$787	$787	$797	$797
2005	$788	$788	$788	$798	$798
2006	$788	$788	$788	$798	$798
2007	$788	$788	$788	$798	$798
2008	$788	$788	$788	$798	$798
2009	$788	$788	$788	$798	$798
2010	$788	$808	$851	$798	$829
2011	$788	$808	$887	$798	$829
2012	$788	$808	$896	$798	$829
2013	$788	$808	$892	$798	$829
2014	$788	$808	$894	$798	$829
2015	$788	$808	$894	$798	$829
2016	$788	$808	$894	$798	$829
2017	$788	$808	$894	$798	$829
2018	$788	$808	$894	$798	$829
2019	$788	$808	$894	$798	$829
2020	$788	$808	$894	$798	$829
2021	$788	$808	$894	$798	$829
2022	$788	$808	$894	$798	$829
2023	$788	$808	$894	$798	$829
2024	$788	$808	$894	$798	$829
2025	$788	$808	$894	$798	$829
2026	$788	$808	$894	$798	$829
2027	$788	$808	$894	$798	$829
2028	$788	$808	$894	$798	$829
2029	$788	$808	$894	$798	$829
2030	$788	$808	$894	$798	$829
2031	$788	$808	$894	$798	$829
2032	$788	$808	$894	$798	$829
2033	$788	$808	$894	$798	$829
2034	$788	$808	$894	$798	$829
2035	$788	$808	$894	$798	$829

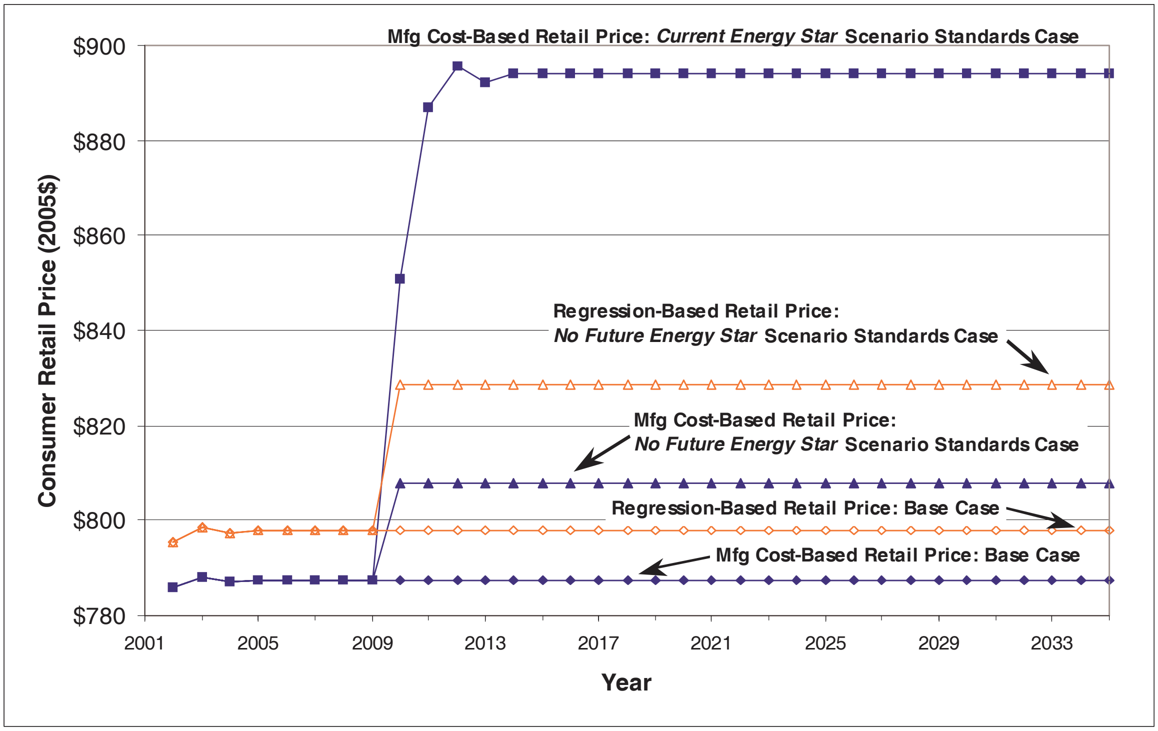

Figure 5-7. Base Case and Standards Case Average Per-Unit Consumer Retail Prices for New Product Shipments: Refrigerator-Freezers with Side-Mount Freezer and with TTD Ice Service

5.3.3 Product Lifetime

As described in the LCC and PBP analysis, the Department estimated the product lifetime from a prior technical support document (TSD) the Department published in 1995 to assess whether amended energy conservation standards were warranted for refrigerator-freezers.[3] The product lifetime from the prior TSD was estimated to be 19 years.

As noted in the LCC and PBP analysis, the length of first ownership is shorter than the product lifetime. The Department has accounted for the length of first ownership in past standards rulemakings, specifically, in the technical analysis that was conducted in support of the most recent clothes washer Final Rule.[4] The shipments and national impact analyses accounted for the length of clothes washer first ownership and how it related to the market of used clothes washers.

For purposes of this national impact analysis for refrigerator-freezers, the Department did not address the issues of first ownership and a used appliance market. If the Department pursues a standards rulemaking, the extent to which first ownership and a used appliance market are addressed will depend on the input of stakeholders.

5.3.4 Electricity Price

As described in the LCC and PBP analysis, the Department calculated electricity prices for the residential sector from the Energy Information Administration (EIA)'s *Annual Energy*

Review (AER) 2003.[5] Electricity prices are provided by EIA in nominal dollars and 2000 dollars for the years 1960–2003. The Department used gross domestic product (GDP) implicit price deflators to convert values into 2005 dollars.[6]

The Department then used EIA's *Annual Energy Outlook 2005* (*AEO 2005)* Reference Case[7] residential electricity price forecast to project prices from 2003 to 2035. The Department used a linear extrapolation based on the last ten years (2015–2025) in the forecast to project prices to the end of the analysis period (2035). Table 5-14 shows the forecasted electricity prices based on a 2003 price of 8.93 cents per kilowatt-hour (¢/kWh).

Table 5-14. Historical and Forecasted Electricity Prices

Year	Price (¢/kWh in 2005$)	Year	Price (¢/kWh in 2005$)
2001	9.19	2026	8.54
2002	8.87	2027	8.56
2003	8.93	2028	8.58
2004	8.86	2029	8.59
2005	8.84	2030	8.61
2006	8.57	2031	8.63
2007	8.25	2032	8.65
2008	8.08	2033	8.67
2009	8.09	2034	8.68
2010	8.07	2035	8.70
2011	8.08	2036	8.72
2012	8.13	2037	8.74
2013	8.20	2038	8.76
2014	8.29	2039	8.77
2015	8.31	2040	8.79
2016	8.29	2041	8.81
2017	8.31	2042	8.83
2018	8.37	2043	8.85
2019	8.45	2044	8.87
2020	8.48	2045	8.88
2021	8.52	2046	8.90
2022	8.50	2047	8.92
2023	8.48	2048	8.94
2024	8.49	2049	8.96
2025	8.52	2050	8.97

Source: EIA *AER 2003*; EIA *AEO 2005.*

5.3.5 Site-to-Source Energy Conversion Factors

The Department calculated energy savings as site energy, which it then converted to source energy— the energy that electric power plants consume. As shown in Table 5-15, the Department used site-to-source energy conversion factors from the *AEO 2005*. The Department extrapolated the values in later years (after 2025) from their relative sources because the *AEO* does not forecast beyond 2025. To arrive at values for these later years, the Department used the forecast's trend from 2015 to 2025 to establish conversion factors in the years 2025 to 2035.

Table 5-15. Site-to-Source Conversion Factors

Year	Site-to-Source Conversion Factor (Btu/kWh)
2004	10,960
2005	10,942
2006	10,916
2007	10,900
2008	10,855
2009	10,805
2010	10,757
2011	10,709
2012	10,662
2013	10,631
2014	10,591
2015	10,541
2016	10,498
2017	10,463
2018	10,419
2019	10,388
2020	10,352
2021	10,329
2022	10,302
2023	10,279
2024	10,259
2025	10,240
2026	10,210
2027	10,180
2028	10,151
2029	10,121
2030	10,092
2031	10,063
2032	10,034
2033	10,005
2034	9,975
2035	9,947

Source: EIA, *AEO 2005.*

5.3.6 Discount Rate

The Department calculated the NPV of cost savings with both a three-percent and a seven-percent real discount rate. It used the three-percent real discount rate to represent the rate at which society discounts future consumption flows to their present value, and the seven-percent real discount rate to represent the average real rate of return on private investment in the U.S. economy. The Department used these discount rates in accordance with the Office of Management and Budget (OMB)'s guidance to Federal agencies on the development of regulatory analysis (OMB Circular A-4, September 17, 2003), and section E, "Identifying and Measuring Benefits and Costs," therein.

5.3.7 Analysis Period

For purposes of calculating the NES and NPV, the Department used an analysis period of 2010 (the assumed effective date of new energy conservation standards) through 2035. For the calculation of the NPV, DOE determined increases in the national consumer retail prices for each year of the analysis period (2010–2035); it determined national electricity cost savings for each year beginning from the start of the analysis period (2010) to the year when products purchased in the year 2035 retired.

5.4 NES AND NPV RESULTS

Table 5-16, Figure 5-8, and Figure 5-9 summarize the NES and NPV due to new energy conservation standards set at 15 percent lower energy consumption than current energy conservation standards. Results of the national impact analysis are provided for the two standards case scenarios (No Future Energy Star and Current Energy Star), the two retail price estimates (manufacturing cost-based or regression analysis-based), and the two discount rates (three percent and seven percent real) considered for the national impact analysis. As noted earlier, regression analysis-based retail prices are applicable only to the No Future Energy Star scenario.

For the No Future Energy Star standards case scenario, the NES due to standards for top-mount and side-mount refrigerator-freezers are 2.4 quads of primary energy (1.1 quads from top-mount refrigerator-freezers and 1.3 quads from side-mount refrigerator-freezers). For the Current Energy Star standards case scenario, the savings are 3.4 quads of primary energy (1.3 quads from top-mount refrigerator-freezers and 2.1 quads from side-mount refrigerator-freezers).

The NPV of standards depends on the scenario, the retail price estimate, and the discount rate. For a discount rate of three percent real, both standards case scenarios have a positive NPV. The NPV of the No Future Energy Star scenario is $10.1 billion with manufacturing cost-based retail prices and $8.0 billion with regression-based retail prices. The NPV of the Current Energy Star scenario is $3.3 billion. For a discount rate of seven percent real, the No Future Energy Star scenario still yields a positive NPV, $3.3 billion with manufacturing cost-based prices and $2.2 billion with regression-based prices, but the NPV under the Current Energy Star scenario becomes negative at -$1.2 billion.

Table 5-16. National Energy Savings and Net Present Value of Standards for Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service & with Side-Mount Freezer and with TTD Ice Service (2010–2035)

Standards Case Scenario	Retail Price Estimate	Discount Rate	NES (quads)			NPV (2005$)		
			Top-Mount	Side-Mount	Total	Top-Mount	Side-Mount	Total
No Future Energy Star	Mfg. Cost	3%	1.1	1.3	2.4	$4.0	$6.0	$10.1
	Regress.					$3.3	$4.7	$8.0
Current Energy Star	Mfg. Cost		1.3	2.1	3.4	$2.4	$0.9	$3.3
No Future Energy Star	Mfg. Cost	7%	1.1	1.3	2.4	$1.3	$2.0	$3.3
	Regress.					$0.9	$1.3	$2.2
Current Energy Star	Mfg. Cost		1.3	2.1	3.4	$0.2	($1.4)	($1.2)

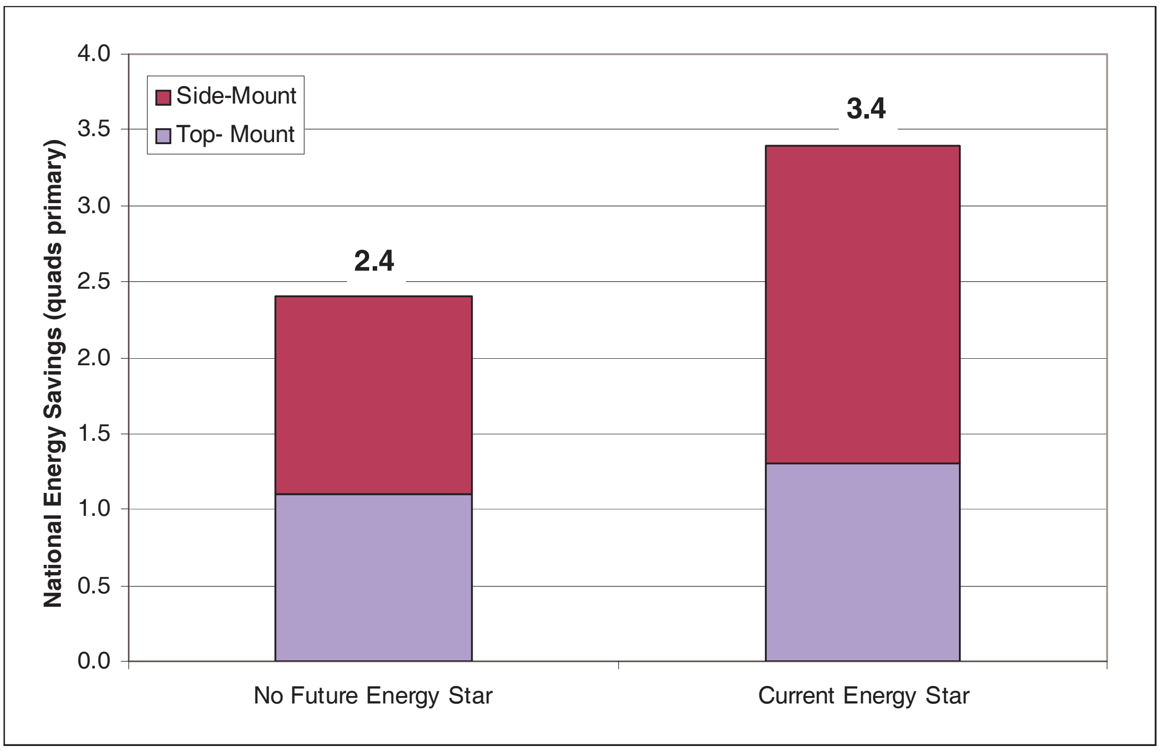

Figure 5-8. National Energy Savings from Standards for Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service & with Side-Mount Freezer and with TTD Ice Service

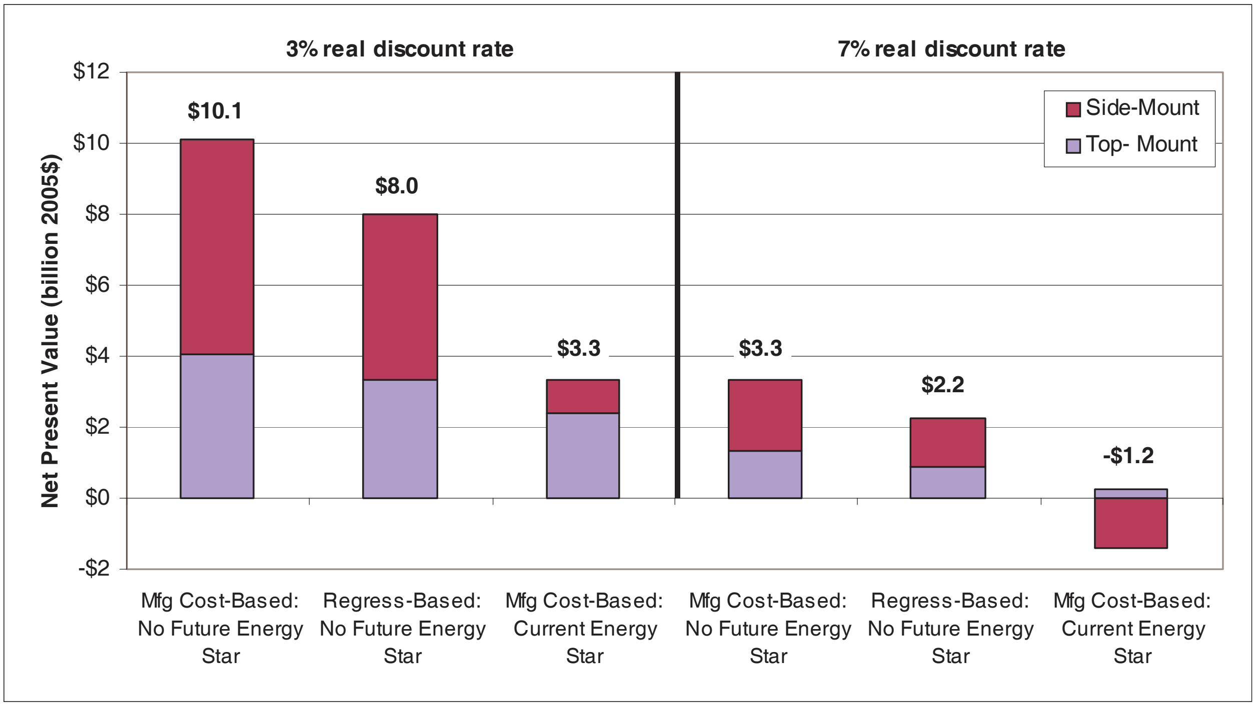

Figure 5-9. Net Present Value from Standards for Refrigerator-Freezers with Top-Mount Freezer and without TTD Ice Service & with Side-Mount Freezer and with TTD Ice Service

REFERENCES

[1] Association of Home Appliance Manufacturers, *Summary Data Tables: Refrigerator-Freezer Data Collection for Cost/Efficiency Information for DOE Petition*, 2005. Information provided by the Association of Home Appliance Manufacturers (AHAM) to the U.S. Department of Energy, May 13, 2005.

[2] The NPD Group, Inc., *The NPD Group/NPD Houseworld – POS, Refrigerators*, January – December 2004, 2005. Port Washington, NY.

[3] U.S. Department of Energy, *Technical Support Document: Energy Efficiency Standards for Consumer Products: Refrigerators, Refrigerator-Freezers, & Freezers*, July 1995. Washington, DC. Report No. DOE/EE-0064.

[4] U.S. Department of Energy, *Final Rule Technical Support Document (TSD): Energy Efficiency Standards for Consumer Products: Clothes Washers*, December 2000. Washington, DC. Chapter 9.

[5] U.S. Department of Energy-Energy Information Administration, *Annual Energy Review 2003*, September 2004. Washington DC. Report No. DOE/EIA-0384(2003). Table 8-10, Average Retail Prices of Electricity, 1960-2003.

[6] U.S. Government Printing Office, Budget of the United States Government: Historical Tables Fiscal Year 2005, Section 10 – Gross Domestic Product and Implicit Outlay Deflators, Table 10.1 – Goss Domestic Product and Deflators Used in the Historical Tables: 1940–2009, 2005. Washington, DC. GPO Access: <http://www.gpoaccess.gov/usbudget/fy05/hist.html>

[7] U.S. Department of Energy-Energy Information Administration, *Annual Energy Outlook 2005*, February 2005. Washington, DC. Report No. DOE/EIA-0383(2005).

CHAPTER 6. MANUFACTURER IMPACT ANALYSIS

The Department carried out a preliminary evaluation of the impact of potential new regulations on manufacturer financial performance, domestic refrigerator-freezer manufacturing capacity and employment levels, and product utility and innovation. A primary focus was to identify the cumulative burden that industry faces from the overlapping effect of new or recent DOE standards and/or other regulatory action affecting the same product or industry. The primary sources of information for this evaluation were the 2005 structured interviews with manufacturers of refrigerator-freezers (see Appendix D). In order to maintain confidentiality, information disclosed by individual manufacturers is not identified with a specific manufacturer. Instead, this evaluation reports only aggregated information and does not disclose sensitive information or identify company-specific information.

6.1 IMPACT ON FINANCIAL PERFORMANCE

The Department received manufacturers' views on what they perceived to be the possible impact of potential new standards on their future profitability. As stated by manufacturers, a new energy conservation standard has the potential to impact financial performance in several different ways. The capital investment needed to upgrade or redesign products and product platforms before they have reached the end of their useful life can require conversion costs that otherwise would not be expended, resulting in stranded investments. In addition, higher efficiency standards can result in higher per-unit costs that may deter some customers from buying higher-margin units with more features, decreasing manufacturer profitability. Manufacturers stated that the prospect of product redesign as a result of standards penalizes established manufacturers and alters the playing field for entry to the market by new competitors who do not carry debt burdens from recent investments in new product lines. In their view, this can decrease the relative barrier for competitors entering the market, thereby increasing market competition, reducing incumbent manufacturer profitability, and decreasing U.S.-based production.

6.1.1 Conversion Costs

Typically, in the absence of new energy efficiency regulations, a refrigerator-freezer production line would have a life cycle of approximately 15 to 20 years. During that period, manufacturers would not make major product changes that altered the underlying platforms. Thus, a standard that took effect and resulted in a major product platform redesign before the end of the platform's life would cannibalize a portion of the earlier capital investments. Based on discussions with manufacturers, most have made significant capital investments to meet the DOE efficiency standard levels that took effect in 2001; new standards that required platform changes could strand assets before the end of their useful life. The 1995 TSD estimated the capital conversion costs for the 2001 standard at approximately 725 million dollars. Based on the interviews, this figure is low by a factor of two compared to the actual level of investment by the refrigerator-freezer industry in the years leading up to and immediately following the 2001 standards implementation. It must be noted, however, that not all these costs can be attributed to efficiency standards since the platform changes entailed other product enhancements and cost reduction initiatives.

The Department asked manufacturers what level of conversion costs they anticipated if new efficiency standards required a 15 percent reduction in unit energy consumption relative to the current standards. The level of expected conversion costs varied widely between manufacturers, depending on such factures as the energy performance of their current products, whether their current products could achieve the 15 percent reduction via component-level modifications or needed platform modifications, and the extent to which manufacturers expected to upgrade their platforms to allow for a future Energy Star level. At a minimum, a typical manufacturer would need to spend approximately 30 million dollars if no platform redesigns were needed. More likely, some manufacturers would need some level of platform redesign to reach a 15 percent improvement, particularly when the investments are taken in context with future Energy Star levels. The potential for costs on the order of several hundred million dollars exists if even a single major manufacturer's product platforms undergo a full redesign. Capital expenditures would account for roughly 75 to 80 percent of the cost, with product development expenses accounting for the remaining portion.

When asked to quantify the investments engendered by a 25 percent efficiency improvement, manufacturers referred to the investment level required by the 2001 standards and gave estimates totaling well over one billion dollars.

6.1.2 Profitability

Several manufacturers indicated that a new standard level would cause existing pressures on margins and profitability to increase because only a limited portion of customers are willing to pay more for energy efficiency. Manufacturers believe that they could not pass on to customers all of the cost increases required to meet the standard since historically, the appliance industry has not able been to recover standard-induced capital costs in prices. Over time industry margins have actually decreased as large manufacturers, who need certain volumes to operate efficiently, are willing to reduce margins to increase volumes. The profit margin impact would be minimized if manufacturers could produce higher-efficiency products at small incremental costs without lowering product utility. However, an increase in unit cost to customers may tend to decrease the quantity of non-energy features that customers purchase, and manufacturers indicated that products with such features can often command greater premiums than energy-efficient products.

In addition, several manufacturers noted that new standards would facilitate the entry of foreign competitors in the U.S. market. Without new standards, a new manufacturer would need to make large capital investments to build production capacity, --investments that existing manufacturers would not need to make. In the case of new standards, however, most manufacturers would need to carry out product platform redesigns for some of their products to meet the new standards. This would neutralize much of the cost advantage from existing infrastructure that current manufacturers have relative to new, foreign-based manufacturers. In fact, should they elect to relocate to a lower cost country to be cost competitive with the new market entrants, conversion costs would tend to be higher for domestic manufacturers due to the additional costs associated with the closure of existing facilities.

Finally, multiple manufacturers noted that product quality and reliability could suffer for a period of time after the new standards are in effect, particularly if a product and its platform required wholesale redesign to meet the standards. This could increase warranty costs to manufacturers as these problems are resolved and, if customers find major quality issues, could damage a manufacturer's reputation and decrease their market share.

6.1.3 Impact on Export Sales

Overall, manufacturers indicated that the export of U.S. refrigerator-freezers to other countries was a small portion of the market. In most cases, new efficiency standards would not have a large impact on export sales except in cases where the standards resulted in a product redesign that would increase product dimensions; product redesign is an important parameter in some export markets.

6.2 IMPACT ON U.S. PRODUCTION AND JOBS

The impact of new efficiency standards on employment is an important consideration in the rulemaking process. In order to assess how domestic employment patterns might be affected by new energy efficiency standards for refrigerator-freezers, the Department posed several questions to manufacturers related to this topic.

Over the past several years, some refrigerator-freezer manufacturers have moved a portion of their production out of the U.S., primarily driven by concerns about profitability and the opportunity for lower labor costs. Mexico is the most common location for both U.S. and foreign manufacturers to establish new production capacity to serve the U.S. refrigerator-freezer market, since it offers low labor rates (relative to the U.S.) and proximity to the U.S. market. Based on information obtained from the interviews, the Department estimates that approximately 25 percent of all residential refrigerator-freezers sold in the U.S. are manufactured in Mexico and that this portion is likely to increase within a few years. Manufacturers indicated that they anticipate new standards would accelerate the trend to manufacture refrigerator-freezers outside of the country. New standards may alter the rate at which refrigerator-freezer production is moved to Mexico because if manufacturers need to make large capital investments to produce redesigned product platforms, they have strong financial incentives to invest in a location with lower labor costs.

Multiple manufacturers commented that as more production moves out of the U.S., design and R&D functions could also be exported. To date, an initial review of the trade news publications by the Department could not confirm this trend.

Recently, Asian, and to a lesser extent, European manufactures, have begun to seek a larger share of the U.S. market. The domestic manufacturers interviewed stated that due to shipping times and costs, these foreign companies would rely primarily upon new production capacity in the U.S. and Mexico to meet the needs of the U.S. market. An initial review of the trade news publications by the Department confirms this trend.

6.2.1 Industry Consolidation

New standards can cause manufacturers to exit one or more portions of the markets affected by the standards. Thus, standards also affect the degree of industry consolidation, that is, the degree to which a limited number of companies dominate a market. At present, four companies, Electrolux, General Electric, Maytag, and Whirlpool, account for a large majority of refrigerator-freezer sales. Recently, several organizations, including a major domestic refrigerator-freezer manufacturer have made offers to purchase Maytag.

Manufacturers indicated that more stringent energy efficiency standards might lead to greater outsourcing for the production of lower-margin units, such as top-mount refrigerator-freezers. For example, since the 2001 rulemaking, at least one major manufacturer has stopped producing top-mount units and elected to source them from another major manufacturer and market them with their brand. If a company currently producing top-mounts needs to undergo major product platform redesign to meet a new standard level, they may decide that the large capital and R&D resource investments would not yield sufficient profits and also may decide to exit that portion of the market.

One manufacturer also noted that the residential freezer market, a subset of the products covered by the petition, already has a high degree of consolidation, i.e., two major market players. Although freezers are not explicitly included in the preliminary analysis, they would be included in a possible future refrigerator-freezer rulemaking.

Ultimately, the decision by any manufacturer to exit refrigerator-freezer production would require an assessment of the linkages between that business and other appliances. Manufacturers and their retail partners generally perceive some value in being a full-line producer. If a manufacturer perceived significant value in other white goods and if the total product line generated acceptable rates of return, it might continue to produce refrigerator-freezers, even in the face of declining company values due to investment in new refrigerator-freezer technology. Alternately, as stated above, manufacturers may elect to label products manufactured by their competitors, effectively concentrating the production of these models.

6.3 IMPACT ON PRODUCT UTILITY AND INNOVATION

New standards can impact purchasers of refrigerator freezers by increasing or decreasing products' utility, e.g., the interior volume or non-energy features. Manufacturers generally believed that more stringent energy efficiency standards, particularly the 25 percent improvement level, would decrease product innovations and, in some cases, result in reduced product utility.

All manufacturers stated that more stringent standards would require re-design of some portion of their products. This consumes research and development (R&D) resources, both human and financial, and directs these assets away from other potential investments that would normally go toward enhancing the functionality of existing products or developing new products. Many manufacturers indicated that they could achieve a 15 percent UEC reduction using component-level changes to products, which would result in more modest diversion of funds. Nonetheless, some manufacturers may still redesign product platforms so that they can continue to produce both standard-level and Energy Star products for marketing reasons. For products and product platforms that would require a complete re-design, a common theme raised by manufacturers when discussing a 25 percent UEC decrease, the required R&D investments would be significantly greater. A platform redesign takes approximately three years and would have a correspondingly larger impact on product innovation and functionality.

Higher efficiency levels could also decrease product utility. Multiple manufacturers indicated that to achieve a 25 percent - or, for some products, a 15 percent - lower UEC, they would use thicker insulation. To a large extent, the maximum dimensions of refrigerator-freezers are fixed by builders, i.e., a standard space exists for refrigerator freezers in kitchens, and manufacturers design units to fit within these dimensions to avoid decreasing their potential market size. This is particularly the case for higher-end counter-depth and built-in products that are designed to have a depth equal to kitchen counters and, practically speaking, whose depth cannot exceed 61cm (24 inches). Consequently, thicker wall insulation would lead to a decrease in interior dimensions and internal volume. In addition, at least one manufacturer noted that reduced unit volume would likely reduce the size of interior features in an attempt to minimize the impact of smaller dimensions of product utility.

More stringent standards could also decrease the range of products available to customers. When presented with a hypothetical new standard representing a 15 percent UEC decrease relative to the current DOE standards, manufacturers indicated that they might discontinue certain products for which it may prove challenging to meet the standard level, such as built-in and counter-depth units. Alternately, they might outsource production of those units and continue to sell units under their brand. When manufacturers were asked about a hypothetical Energy Star UEC 25 percent lower than the current DOE standards, several manufacturers stated that they might discontinue making some or all Energy Star products. Manufacturers noted that they often do not necessarily maintain their margins for higher-cost Energy Star units because they believe that consumers do not think that the additional cost can justify the relatively modest savings. To date, however, many have produced Energy Star units because they need them to have their product line marketed via major retail chains, to sell to government, and to have their products part of utility rebate programs. As discussed previously, achieving a 25 percent UEC reduction would require extensive product and product platform redesign for most manufacturers. For certain mainstream products, multiple manufacturers indicated that the market benefit of having Energy Star would not be sufficient to overcome the capital costs required to re-design the products and production to meet the new Energy Star performance level. In other cases, manufacturers are not sure if they could produce cost-effective units that achieve the 25 percent reduction relative to the current standard.

6.4 CUMULATIVE BURDEN

When assessing the benefits and burdens of a potential revision of product energy standard levels, the Department considers several factors in addition to energy savings potential and cost-effectiveness. It also takes into account the regulatory burden that will impact the manufacturers of the product at or around the time the new standards would come into effect. Based on its own research and discussions with manufacturers, the Department identified several existing or pending regulations relevant to residential refrigerators, including:

- Existing energy efficiency standard for refrigerator-freezers
- Insulation blowing agent phase out
- Energy efficiency standards for other products made by the same manufacturers
- State energy efficiency standards
- International energy efficiency standards
- Waste disposal and recycling requirements

Complying with these regulations requires that corporations invest both human and capital resources. The following subsections discuss in greater detail regulations impacting the refrigerator-freezer industry.

6.4.1 Existing Energy Efficiency Standard for Refrigerator-Freezers

In 1987, the National Appliance Energy Conservation Act (NAECA) was signed into law establishing minimum energy efficiency standards for residential refrigerators, refrigerator-freezers, and freezers. NAECA specified for twelve product classes the maximum allowable energy in kilowatt-hours per year for products manufactured on or after January 1, 1990. Subsequent to the NAECA requirements, revised minimum efficiency standards for residential refrigeration products became effective first in 1993 then again in 2001. The minimum efficiency standards of 1993 eliminated 99 percent of the models previously manufactured and increased efficiency by 25 to 30 percent relative to the initial NAECA requirements. The minimum efficiency standards that became effective on July 1, 2001 increased the efficiency of the most popular product class, top mount refrigerator-freezers with auto-defrost, by approximately 30 percent relative to the 1993 standards.

Table 6-1 presents values from the 1995 TSD for estimates of the tooling, equipment, buildings, and research and development investments needed to convert from producing equipment that performed at the TSD Baseline level to units whose UEC meets either the 2001 standard level or a level 15 percent lower than the 2001 standard for a typical large manufacturer.[1] The values are very low compared to the actual expenditures that manufacturers reported during the interviews.

Table 6-1. Estimated Investments and Expenses to Reach Various Efficiency Levels, from 1993 Standard Levels

Model Type	TSD Baseline to 2001 (1992$, millions)	TSD Baseline to 15% Below 2001 (1992$, millions)	Comments
Top-Mount	$154	$83 / $254	$83 million path used vacuum panels
Side-Mount	$20	$100	

Note: The TSD Baseline energy use is 16 percent below the 1993 Standard for the side-mount
Source: DOE 1995 TSD.

6.4.2 Insulation Blowing Agent Phase Out

Production of refrigerator foam insulation uses a blowing agent. The Montreal Protocol required that the U.S. begin to phase out the blowing agent HCFC-141b beginning in January 2003. This impacted refrigerator-freezers produced in the U.S. and caused manufacturers to switch to other blowing agents with a much lower ozone depletion potential, such as HFC-245fa. Several manufacturers indicated that they have switched to HFC-245fa. Only one company, however, holds a license to produce HFC-245fa for the U.S. market. This represents a significant challenge for manufacturers to control product costs and avoid future production disruptions. Alternative blowing agents such as HFC-134a or cyclopentane have other drawbacks, such as lower thermal resistance and/or increased implementation costs due to flammability. On the other hand, use of HCFC-141b for refrigerators imported into the U.S. may continue in countries with a later phase-out date, such as Mexico.

6.4.3 Energy Conservation Standards for Other Products Made by the Manufacturers of Refrigerator-Freezers

Most manufacturers of refrigerator-freezers produce other white goods that have been subject to NAECA, including dishwashers, clothes washers, and clothes dryers. Notably, new efficiency standards will come into effect for clothes washers in 2007. The capital conversion costs to increase clothes washer efficiency from the level established in the rule published in May, 1991 (taking effect in May, 1994) to that taking effect in 2004 were estimated to be $631 million for the entire industry.[2]

6.4.4 State Energy Conservation Standards

In addition to Federal regulations, certain states have proposed conservation standards for similar types of products. For example, California's Title 20 regulates wine chiller energy consumption.[3]

6.4.5 The Energy Policy Act of 2005

On August 8th, 2005, President George W. Bush signed the Energy Policy Act of 2005 (EPACT 2005) into law.[4] EPACT 2005 contains several energy efficiency provisions, including energy efficiency standards for a host of consumer products and commercial equipment, directives for the Secretary of Energy to set standards for other products and equipment, and a package of financial incentives for efficient products, buildings, and vehicles. The manufacturer incentives for residential refrigerators and the standards for commercial refrigerators, freezers and refrigerator-freezers, in particular, will affect the same manufacturers impacted by the new DOE standard considered in this document.[e] The following reviews the standards and financial incentives as provided in EPACT 2005 and signed into law, and highlights relevant products in more detail. Table 6-2 provides a general overview of those products and standards affected by EPACT 2005.

---

[e] According to the Act, 'refrigerators' refers to residential model automatic defrost refrigerator-freezers with an internal volume of at least 16.5 cubic feet.

Table 6-2.Product and Equipment Measures Overview

General Measure Descriptions and Covered Products & Equipment
Tax Incentives
Residential Refrigerators (refrigerator-freezers) Residential Clothes Washers Residential Dishwashers New and Existing Homes Commercial Buildings Heating and Cooling Equipment Stationary Fuel Cells Transportation Tax Incentives
Standards
Commercial Refrigerators, Freezers, and Refrigerator-Freezers Automatic Commercial Ice Makers Dehumidifiers Commercial Clothes Washers Commercial Packaged Heating and Air Conditioning Equipment Ceiling Fans and Ceiling Fan Light Kits Torchiere Lamps Fluorescent Lamp Ballasts Compact Fluorescent Lamps Low-Voltage, Dry-Type Distribution Transformers Exit Signs Traffic Signal Modules and Pedestrian Signals Pre-Rinse Spray Valves Mercury Vapor Lamp Ballasts (Phaseout) Unit Heaters
Rulemaking Directives
Commercial Refrigerators, Freezers, and Refrigerator-Freezers Refrigerated Bottle or Canned Vending Machines Battery Chargers and External Power Supplies Ceiling Fans and Ceiling Fan Light Kits

EPACT 2005 provides tax credits to manufacturers for the production of energy-efficient residential refrigerators, clothes washers, and dishwashers. The total credit for residential refrigerators is equal to an applicable credit amount multiplied by the eligible production. Table 6-3 highlights the applicable credit amount along with credit limitations. According to EPACT 2005, eligible production for refrigerators equals the number of appliances produced in a year over 110% of the average number of appliances produced during the preceding three-year period.

Table 6-3. Refrigerator-Freezer Tax Incentives

Savings	Applicable Credit Amount	Limitations	Eligible Production
15%	$75	Up to $20,000,000	Equals the number of appliances produced in a year over 110% of the average number of appliances produced during the preceding three-year period.
20%	$125	Up to $75,000,000*	
25%	$175		

Notes: According to EPACT 2005, 'refrigerators' refers to residential model automatic defrost refrigerator-freezers with an internal volume of at least 16.5 cubic feet. Applicable equipment includes refrigerator-freezers manufactured in 2006 with savings between 15-20% (15%), and those manufactured in 2006 or 2007 with savings between 20-25% (20%) or at least 25%. Percentage savings refer to 2001 energy conservation standards.
* Reduced by the amount of credit taken in previous years

Some of the same manufacturers regulated by standards for residential refrigerators, freezers, and refrigerator-freezers are also covered under other product standards in EPACT 2005. For example, EPACT 2005 sets standards for products and equipment including dehumidifiers, commercial clothes washers, commercial refrigerators, freezers, and refrigerator-freezers, commercial heating and cooling, and vending machines.

The increased stringency of standards for regulated equipment varies. However, new standards for equipment mentioned above generally coincide with recent or existing Energy Star standards. For example, the new energy consumption standards for solid door refrigerators, freezers, and refrigerator-freezers, as specified in EPACT 2005, are roughly the same as current energy star criteria. The new standards for dehumidifiers generally raises the energy factor to existing Energy Star criteria, if not slightly below in some cases[f] and the new energy factor standard for commercial clothes washers matches the pre-2004 Energy Star standard.[5,6,7]

Many provisions of the recently passed Energy Policy Act of 2005 may have some impact on manufacturers; including State consumer rebates for Energy Star products, as well as the federal manufacturer tax incentives and product standards noted above. However, this report does not attempt to project the impact of these new provisions.

6.4.6 International Energy Efficiency Regulations

Most refrigerator-freezer manufacturers sell a small portion of their total production to countries besides the U.S. In those cases, the products must meet the standards for each country. Based on manufacturer interviews, companies may design some units to meet more stringent standards than the U.S., e.g., for the European Union, to minimize the number of product variations. In general, however, most other countries have less stringent standard levels than the U.S.

6.4.7 Waste Disposal and Recycling Requirements

Several manufacturers noted that their products exported to Europe and the Canadian province of Ontario will fall under recent laws mandating that manufacturers of electronic and electrical equipment, which includes residential refrigerators and freezers, take back such equipment from consumers in a manner that is at least cash-neutral to the consumer. In January 2003, the European Union approved the “Waste from Electronic and Electrical Equipment” (WEEE) directive with the goal of “promoting waste recovery with a view to reducing the quantity of waste for disposal and saving natural resources, in particular by reuse, recycling, composting, and recovering energy from waste”. Refrigerators (and other white goods) fall under this regulation. It requires that manufacturers selling a range of products, including refrigerators and freezers, in the EU dispose of, recycle, or recover goods that they manufacture after August 13, 2005. Toward this end, it requires that “users of electrical and electronic equipment from private household should have the possibility of returning WEEE at least free of charge … each producer should be responsible for financing the management of the waste from his own

[f]Note: The new standards categorize capacity groupings into five bins as opposed to the three originally used by Energy Star so categories overlap.

products." Producers also have explicit minimum recovery rates that they must achieve by December 31, 2006, i.e., in the case of residential refrigerators, refrigerator-freezers, and freezers; it equals 80 percent of refrigerators by weight. It also requires the producers to recover portions of the waste from products manufactured prior to August 13, 2005, based on their past market share.[8]

Under the Ontario Waste Diversion Act of 2002, the government of the Canadian province of Ontario has recently requested the development of a waste diversion program for WEEE materials, including refrigerators.[9,10] Although the process for WEEE recovery and required recovery rates have yet to be established, it also requires manufacturers to take responsibility for diversion of WEEE.[6,11] The request commissions a study for completion in mid-2005 that will explicitly include recommendations on the adequacy of a year-long timeline for developing the program. This implies that a program could be finalized in 2006, with a launch possible in 2007.[6,12]

At present, the U.S. does not have waste disposal or recycling requirements for refrigerator-freezers. Some manufacturers indicated that they believe similar requirements could be extended to all of Canada and, in the future, potentially to the U.S. This could cause manufacturers to alter product re-designs to facilitate product recycling. At this point in time, the Department is not familiar with any similar legislation in the United States, but acknowledges that the Ontario legislation could have an impact on refrigerator-freezer design because of the tight integration of the U.S. and Canadian white goods markets.

6.4.8 Restriction of Hazardous Substances

In early 2003, the EU published the "The Restriction of Hazardous Substances in Electrical and Electronic Equipment (ROHS)" Directive. This directive pertains to white goods covered by the WEEE regulation (discussed above) and explicitly states that "Member States shall ensure that, from 1 July 2006, new electrical and electronic equipment put on the market does not contain lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE)." Multiple manufacturers noted that this would impact refrigerator-freezer units that they export to Europe. In addition, the directive states that the European Commission and the Council of the EU can agree to prohibit "other hazardous substances" "as soon as scientific evidence is available" in the future, i.e., other materials may be prohibited from refrigerators sold to the EU in the future.[13] A limited number of exemptions exist, many for mercury (in lamps) and lead[9], as well as for defense products and certain types of medical equipment.[14] The European Committee of household appliance manufacturers, CECED, presents the following "critical examples of applications [that] are banned"[10]:

- Lead in solder for electrical and electronic parts
- Lead in PVC and other types of plastics
- Chromium VI on screws and other metallic parts, and
- Platings and coatings using the materials (each layer is considered as a separate part).

6.4.9 Microwave Oven Radio Frequency Emission Regulations

Microwave ovens have recently been subject to FCC requirements, which limit radio frequency emissions onto the power lines serving these units[1]. Previously microwave ovens were subject only to regulations governing externally leaked emissions to assure safety of nearby people. Microwave ovens have been regulated since October 1971 by the FDA for limitation of radiated emissions (the limit is 5 milliwatts of microwave radiation per square centimeter at approximately 2 inches from the oven surface). The recent FCC regulation addresses possible interference of microwave ovens with power line carrier and RF devices resulting from emissions of RF frequencies onto electric power lines. The regulation adopts the requirements of the international standard IEC/CISPR Publication 11, which sets limits for conducted emissions in the frequency ranges 9kHz to 30MHz. These standards took effect July 10, 2005, for all microwave ovens sold in the U.S.

6.4.10 Arc-Fault Protection for Window Air-Conditioning Unit Power Cords

The 2002 National Electric Code (which is referenced by many local codes) added requirement 440.65 which states that window air-conditioners with single-phase cord and plug electrical connection must incorporate either arc fault protection or leakage current detection in the power supply cord within 12" of the attachment plug. This requirement took effect August 1, 2004. These changes aim to reduce the risk of fire associated, for example, with the fatigue of conductors and insulation leading to development of high-impedance arcs against which conventional circuit breakers provide no protection.

6.4.11 Flammable Vapor Resistance Standard for Water Heaters

A voluntary standard has been adopted by water heater manufacturers to improve resistance of residential water heaters to igniting flammable vapors from external sources such as spilled gasoline. The standard mandates design changes, which make the water heaters resistant to igniting flammable vapors outside of the water heater. Initial adoption of the standard for conventional (i.e. atmospherically-fired, natural draft vented) 30, 40, and 50-gallon residential gas water heaters occurred July 1, 2003, and it was extended to power vented and larger models on July 1, 2005.

6.4.12 Water Factor Standards for Clothes Washers

Water factor standards for clothes washers have been pursued by California and other states. In California, water factor standards for commercial clothes washers took effect in 2004. California standards for residential clothes washers call for a maximum water factor (gallons of water used per cubic feet of washer capacity) of 8.5 to take effect on January 1, 2007, and a water factor of 6.0 by January 1, 2010. California must get a waiver from DOE, since regulation of residential appliance efficiency is under the jurisdiction of the federal government. A request for a waiver has been submitted to DOE. A number of states have also adopted or are considering the same commercial clothes washer standards, which were enacted in California.

6.4.13 Indoor Air Quality Regulations for Ranges and Ovens

In 2002 Assembly Bill 1173 (Keeley, 2002; California Health and Safety Code Section 39930) was enacted. This bill required the California Air Resources Board to prepare a report on the growing issue of Indoor Air Quality. The report was completed in July 2005[2]. One of the sources of indoor pollutants discussed in the report is unvented cooking appliances fired with natural gas or propane, such as residential ranges or ovens. Such appliances were identified as sources of carbon monoxide, nitrogen oxides, particles, soot, and polycyclic aromatic hydrocarbons. The authors put these appliances on a list of "High Priority Source Categories for Mitigation" with such sources as ozone-generating air cleaners, tobacco smoke, and radon. One of the key mitigation strategies mentioned for such appliances is to require venting, an action, which would require significant design modifications for such appliances. Since the report has just recently been submitted to the legislature, it is not clear at this stage whether any such regulations are likely to be considered for passage into law.

6.4.14 Impact of Cumulative Burden on Small Manufacturers

The manufacturer interviews indicated that smaller refrigerator manufacturers typically have smaller corporate research and development staffs than larger manufacturers. Although small manufacturers often have a more limited product range than major manufacturers, the effort to address some aspects of regulations are relatively fixed and do not scale directly with the number of products or product platforms produced. Consequently, the cumulative burden of regulations will tend to place more of a burden on smaller manufacturers because of their more limited resources.

REFERENCES

1 U.S. Department of Energy, *Technical Support Document: Energy Efficiency Standards for Consumer Products: Refrigerators, Refrigerator-Freezers, & Freezers*, July 1995. Washington, DC. Report No. DOE/EE-0064.

2 U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, *Final Rule Technical Support Document (TSD): Energy Efficiency Standards for Consumer Products: Clothes Washers*, December 2000. Washington, DC. Available at: http://www.eere.energy.gov/buildings/appliance_standards/residential/clwash_0900_r.html.

3 California Energy Commission, *Title 20 Appliance Efficiency Regulations*, April 2005. Sacramento, CA. Report No. CEC 400-2005-012. Available at: http://www.energy.ca.gov/2005publications/CEC-400-2005-012/CEC-400-2005-012.PDF.

4 U.S. Congress. Energy Policy Act of 2005 (H.R. 6). Conference report passed by House on July 28th, 2005 and passed by Senate on July 29th, 2005. Signed into law August 8th, 2005.

5 Energy Star Program. "Clothes Washers Key Product Criteria." Available online at http://www.energystar.gov/index.cfm?c=clotheswash.pr_crit_clothes_washers

6 ______. "Energy Star Program Requirements for Commercial Solid Door Refrigerators and Freezers Eligibility Criteria" http://www.energystar.gov/ia/partners/product_specs/eligibility/commer_refrig_elig.pdf

7 ______. "Energy Star Program Requirements for Dehumidifiers: Partner Commitments." Available online at http://www.energystar.gov/ia/partners/product_specs/program_reqs/dehumid_prog_req.pdf

8 European Union, "Directive 2002/96/96/EC of the European Parliament and of the Council of 27 January 2003 on Waste Electrical and Electronic Equipment (WEEE)," *Official Journal of the European Union*, pp. L37/24-L37/38. Available at: http://europa.eu.int/eur-lex/pri/en/oj/dat/2003/l_037/l_03720030213en00240038.pdf.

9 Waste Diversion Ontario, *Waste Diversion Act, 2002* (Bill 90)*,* Ascended to on June27. Available at: http://www.elaws.gov.on.ca/DBLaws/Source/Statutes/English/2002/S02006_e.htm.

10 Ontario, Letter by L. Dombrowsky, Minister of the Environment of Ontario, Canada, to B. Balkisson, Chair, Waste Diversion Ontario, Dated 20 December, 2004. Available at: http://www.ene.gov.on.ca/envision/land/WDA/electronics/letter122004.pdf.

11 Waste Diversion Ontario, "Waste Electrical and Electronic Equipment," Ontario Regulation 393/04 – Made Under the Waste Diversion Act, 2002, Made and Filed 14 December, 2004, *Ontario Gazette,* January 1, 2005. Available at: http://www.elaws.gov.on.ca/DBLaws/Source/Regs/English/2004/R04393_e.htm.

[12] McGuire, J.M., "Canada Including Appliances in WEEE Program," *Appliance Design*, April 1, 2005. Available at: http://www.ammagazine.com/CDA/ArticleInformation/features/BNP__Features__Item/0,2606,147722,00.html.

[13] European Union, "Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment", *Official Journal of the European Union*, L 37, February 13, 2003, pp. 19 – 23. Available at: http://europa.eu.int/eurlex/pri/en/oj/dat/2003/l_037/l_03720030213en00190023.pdf.

[14] CEDED, "RoHS Guide," Frequently Asked Questions about Directive 2002/95/EC, PP 05-03, February 9, 2005. Available at: http://www.aham.org/library/files/PP%200503%20RoHS%20Guide.pdf.

APPENDIX A. AHAM DATA SUBMITTAL REQUEST

Excerpt from AHAM's request to manufacturers for cost data, described above in the *AHAM Data Submittal and Consolidation* Section, is reproduced below.

Please return the attached survey, indicating the average **incremental production cost** to take your basic models in the categories shown from the current DOE minimum efficiency level to 15% better. In other words, if it costs $200 to produce a basic model at the current baseline minimum efficiency level, and it costs $230 to make it 15% more efficient, the incremental cost difference is $30. If you have more than one basic model at the minimum efficiency level in each of the size categories indicated, average the incremental costs and show that number.

We want to submit an aggregate shipment weighted average, so please indicate your approximate annual shipment volumes for each category. Also, in order to provide the contractors with some sensitivity around the average numbers, for those categories where you have more than one basic model, please indicate the minimum and maximum incremental costs.

A description of the costs to include are noted under the tables on the survey form attached.

Shipments

For the Top Freezer and Side-By-Side tables, in the last column please indicate the total shipment numbers for all models (those that are already Energy Star compliant and those that are not). The cost should be the average, minimum or maximum cost to raise the units from current DOE compliant models to the current DOE Energy Star level. For the tables of the New Energy Star levels for Top Freezer and Side-By-Side, please indicate in the last column an approximate number of new Energy Star units that might be shipped, given an approximate Energy Star level as described below.

Another Element

We would also ask that you consider another element in the cost of refrigerator efficiency improvements. If the minimum efficiency level is raised to the current Energy Star level, models will meet the existing Energy Star level and this will result in DOE Energy Star office seeking an increase in the Energy Star qualification level. We believe that the cost of increasing some portion of your models to the NEW Energy Star level should be accounted for in this efficiency/cost data collection. Obviously, it is difficult to envision what this new Energy Star level might be. For purposes of this data collection, we would suggest that the companies estimate the cost of having some number of units to an Energy Star level equivalent to the energy 25% less than today's DOE Minimum Efficiency level across all the categories. The shipment numbers in the far right column would then be the approximate number of units that will then be sold as the new Energy Star units. We recognize this is a hypothetical estimate. We have included two new tables in the enclosed form. We need this information separately in order to discuss this scenario with DOE and the contractor.

CONFIDENTIAL Refrigerator-Freezer Data Collection for Cost/Efficiency Information for DOE Petition

Top Freezers – Auto Defrost

Size[2], Ft.^{3}	**Average** *Incremental Cost* per product to Achieve 15% Better Eff. than Min. DOE Std	**Minimum**[4] *Incremental Cost* per product to Achieve 15% Better Eff. than Min. DOE Std	**Maximum**[5] *Incremental Cost* per product to Achieve 15% Better Eff. than Min. DOE Std	Approximate Total Annual Shipments
14 – 17				
18 – 20				
21 – 22				
23 – 25				

Top Freezers – Auto Defrost—Increase for New Energy Star Level (Approximately 25% less energy than today's DOE Standard)

Size[2], Ft.^{3}	**Average**[3,7] *Incremental Cost* per product to increase to New Energy Star level	**Minimum**[4] *Incremental Cost* per product to increase to new Energy Star Level	**Maximum**[5] *Incremental Cost* per product to increase to new Energy Star Level	Approx. Annual Shipments of New Energy Star units
14 – 17				
18 – 20				
21 – 22				
23 – 25				

Side By Sides – Auto Defrost with Through-the-Door Ice & Water

Size[2], Ft.^{3}	**Average**[1,3] *Incremental Cost* per product to Achieve 15% Better Eff. than Min. DOE Std	**Minimum**[4] *Incremental Cost* per product to Achieve 15% Better Eff. than Min. DOE Std	**Maximum**[5] *Incremental Cost* per product to Achieve 15% Better Eff. than Min. DOE Std	Approximate Total Annual Shipments
18 – 20				
21 – 23				
24 – 26				
27 – 30				

Side By Sides – Auto Defrost with Through-the-Door Ice & Water—Energy Star (Approximately 25% less energy than today's DOE Minimum)

Size[2], Ft.^{3}	**Average**[3,7] *Incremental Cost* per product to increase to New Energy Star level	**Minimum**[4] *Incremental Cost* per product to increase to new Energy Star Level	**Maximum**[5] *Incremental Cost* per product to increase to new Energy Star Level	Approximate Annual Shipments of New Energy Star Units
18 – 20				
21 – 23				
24 – 26				
27 – 30				

1. Incremental cost data (in U.S. $) includes the materials, burdened labor, and amortization of capitol expense needed to take basic models from the current minimum DOE baseline efficiency standard to a 15% improvement in energy efficiency.
2. For sizes between the ranges shown above, just include units in the nearest size category.
3. In the "Average" column, average the incremental cost for all products in that size range.
4. For the "Minimum" column, show the incremental cost for the basic model with the lowest associated cost.
5. For the "Maximum" column, show the incremental cost for the basic model with the highest associated cost.
6. There are a variety of different ways manufacturers may choose to achieve the higher efficiency level (e.g., more insulation, better gaskets, improved control and defrost schemes, more efficient compressors and fan motors, etc.). All manufacturers will not use the same design options for all models. Therefore, instead of listing design options (some of which may include proprietary information) we are choosing to just show the incremental cost associated with whatever means a manufacturer may choose, without disclosing each manufacturers' specific approach.
7. The incremental cost to achieve the New Energy Star levels would be the cost to raise whatever current units or platforms to the new (hypothetical) Energy Star level approximately 25% improvement in energy over today's DOE Minimum Efficiency level.

APPENDIX B. CONSUMER RETAIL PRICE DATASET: SUMMARY DATA AND REGRESSION ANALYSIS DETAILS

Table B-1 provides the variable statistics for the top-mount and side-mount refrigerator-freezers from The NPD Group dataset that were used for establishing the baseline consumer retail price and the incremental retail price of current Energy Star products.

Table B-1. Variable Statistics for Basic Side-Mount and Top-Mount Refrigerator-Freezers

	Side-Mount			Top-Mount		
Explanatory Variable	**Mean**	**Minimum**	**Maximum**	**Mean**	**Minimum**	**Maximum**
Refrigerator Size and Efficiency Variables						
1. Price	896.6	65.0	1397.2	552.5	53.0	4327.0
2. Capacity (cu. ft.)	24.1	18.0	27.0	18.3	8.5	26.0
3. Electricity use (kWh/yr)	NA	NA	NA	NA	NA	NA
4. Energy Star	0.5	0.0	1.0	0.4	0.0	1.0
5. Sales	1866.5	1	58460	2602	1	104649
Refrigerator Attributes						
1. Through door Ice and Water	0.9	0.0	1.0	0.1	0.0	1.0
2. Icemaker Standard	0.0	0.0	1.0	0.2	0.0	1.0
3. Water Filter	0.9	0.0	1.0	0.2	0.0	1.0
4. Contoured Door	0.1	0.0	1.0	0.1	0.0	1.0
5. Meat and Crisper Drawers	0.6	0.0	1.0	0.3	0.0	1.0
6. Glass Shelves	0.2	0.0	1.0	0.3	0.0	1.0
7. Wire Shelves	0.0	0.0	1.0	0.2	0.0	1.0
8. Spill proof Shelves	0.7	0.0	1.0	0.4	0.0	1.0
Refrigerator Brands						
1. Amana	0.1	0.0	1.0	0.0	0.0	1.0
2. Avanti pro	NA	NA	NA	0.0	0.0	1.0
3. Danby	NA	NA	NA	0.0	0.0	1.0
4. Frigidaire	0.2	0.0	1.0	0.2	0.0	1.0
5. General Electric	0.3	0.0	1.0	0.3	0.0	1.0
6. Haier	0.0	0.0	1.0	0.0	0.0	1.0
7. Hot Point	0.0	0.0	1.0	0.0	0.0	1.0
8. Kitchen aid	0.0	0.0	1.0	0.1	0.0	1.0
9. LG Electronics	0.1	0.0	1.0	0.0	0.0	1.0
10. Magic Chef	NA	NA	NA	0.0	0.0	1.0
11. Maytag	0.0	0.0	1.0	0.1	0.0	1.0
12. Roper	0.0	0.0	1.0	0.0	0.0	1.0
13. Viking	0.3	0.0	1.0	NA	NA	NA
14. Summit	NA	NA	NA	0.0	0.0	1.0
15. Whirlpool	0.3	0.0	1.0	0.2	0.0	1.0

Table B-2 shows the details of the "long" regression analysis performed to establish the retail price increment of current Energy Star products for top-mount refrigerator-freezers. There are two sets of results; one set summarizes the details for the non-sales-weighted regression while the other set summarizes the details for the sales-weighted regression.

Table B-2. Details of the "Long" Regression Analysis to determine the Energy Star Retail Price Increment: Top-Mount Refrigerator-Freezers

Top-Freezer Price Regression

Refrigerator Price, dependant variable

	regression coefficients	**statistical significance**
	(Δprice/Δenergy star)	t(362)
Focus Variables		
Intercept	295.47	7.44
Energy Star	44.39	4.63
Total volume	5.97	3.48
Attribute Variables		
No through door Ice and Water	52.32	2.35
Ice only	32.03	0.98
No Icemaker	-61.07	-3.92
Icemaker optional	-41.72	-2.97
No Water filter	5.56	0.34
Not contoured door	-1.44	-0.09
Crisper drawer only	-1.82	-0.17
Wire shelves	-29.60	-2.39
Glass shelves	-3.13	-0.27
Plastic shelves	-82.21	-1.79
Brand Variables		
Amana	9.97	0.28
Avantipro	-35.41	-1.08
Danby	-44.61	-1.38
Frigidaire	-20.84	-1.50
GenElec	28.88	2.24
Haier	-1.33	-0.05
Hotpoint	-65.50	-3.44
Kitchenmaid	65.72	2.48
LGElec	45.51	1.43
MagicChef	-51.19	-1.75
Maytag	43.10	2.38
Roper	-29.16	-1.55

Highlighted coefficients are significant at the 95% level.

Sales-weighted Top-Freezer Price Regression

Refrigerator Price, dependant variable

	regression coefficients	**statistical significance**
	(Δprice/Δenergy star)	z
Focus Variables		
Intercept	223.7	385.1
Energy Star	39.3	350.8
Total volume	11.8	878.1
Attribute Variables		
No through door Ice and Water	121.0	214.7
Ice only	70.6	115.9
No Icemaker	-51.2	-493.1
Icemaker optional	-36.4	-412.1
No Water filter	-26.5	-116.3
Not contoured door	-53.1	-331.0
Crisper drawer only	-3.8	-39.9
Wire shelves	-49.5	-487.3
Glass shelves	-12.1	-150.4
Plastic shelves	-38.5	-36.8
Brand Variables		
Amana	73.5	132.1
Avantipro	-9.3	-31.6
Danby	24.7	90.8
Frigidaire	-39.1	-373.2
GenElec	-3.9	-25.9
Haier	-28.9	-150.3
Hotpoint	-29.3	-74.8
Kitchenmaid	65.0	43.7
LGElec	91.1	223.3
MagicChef	-65.0	-169.4
Maytag	38.3	184.1
Roper	-40.4	-380.7

Highlighted coefficients are significant at the 95% level.

Table B-3 shows the details of the "long" regression analysis performed to establish the retail price increment of current Energy Star products for side-mount refrigerator-freezers. There are two sets of results; one set summarizes the details for the non-sales-weighted regression while the other set summarizes the details for the sales-weighted regression.

Table B-3. Details of the "Long" Regression Analysis to determine the Energy Star Retail Price Increment: Side-Mount Refrigerator-Freezers

Side by Side Price Regression

Refrigerator Price, dependant variable

	regression coefficients	**statistical significance**
	(Δprice/Δenergy star)	t(283)
Focus Variables		
Intercept	415.2	1.8
Energy star	60.4	2.4
Capacity	6.3	0.8
Attribute Variables		
No through door Ice and Water	113.4	1.8
No Icemaker	-58.1	-0.7
No water filter	7.8	0.2
Not contoured doors	98.6	2.1
Crisper drawers	7.8	0.3
Wire shelves	-63.4	-0.3
Glass shelves	68.5	0.4
Spillproof shelves	105.1	0.6
Brand Variables		
Roper	-118.0	-0.9
Amana	-48.6	-0.5
Frigidaire	10.6	0.1
General Electric	0.1	0.0
Hotpoint	-184.6	-1.6
Kitchenmaid	53.4	0.5
Maytag	22.1	0.2
Whirlpool	5.9	0.1

Highlighted coefficients are significant at the 95% level.

Sales-Weighted Side by Side Price Regression

Refrigerator Price, dependant variable

	regression coefficients	**statistical significance**
	(Δprice/Δenergy star)	z
Focus Variables		
Intercept	125.78	30.86
Energy Star	84.97	340.21
Capacity	25.65	287.17
Attribute Variables		
No through door Ice and Water	89.27	47.16
No Icemaker	-22.14	-7.94
No Water filter	26.10	34.66
Flat, uncontoured Door	-38.55	-36.61
Crisper drawer (no meat drawer)	-78.95	-284.10
Wire shelves	-115.22	-21.87
Glass shelves	-53.75	-12.70
Plastic shelves	19.63	4.63
Brand Variables		
Amana	137.98	46.81
Frigidaire	67.28	26.27
GenElec	183.12	71.09
Hotpoint	-6.93	-1.73
Kitchenmaid	184.94	25.04
Maytag	179.26	68.89
Roper	3.37	1.30
Whirlpool	122.21	47.91

Highlighted coefficients are significant at the 95% level.

APPENDIX C. DETAILS OF FOCUSED MATCHED PAIRS

Table C-1 and Table C-2 show the details of the focused matched pair analysis for top-mount and side-mount refrigerator-freezers, respectively. Details include the annual energy consumption, retail prices, and model features.

Table C-1. Top-Mount Refrigerator-Freezer Matched Pairs

Manufacturer and Model Data				Volume Data (cu. ft.)				Energy Use Data (kWh/yr)		
Category	Manufacturer	Brand	Model Number	Capacity	Fresh Food Capacity	Freezer Capacity	Adjusted Volume	Energy Star Threshold	Annual Energy Use	Delta Energy Use
Baseline	GE	GE	GTS22KBPWW	21.7	15.4	6.4	25.7	448.7	529	81
Energy Star	GE	GE	GTH22KBRWW	21.7	15.4	6.4	25.7	448.7	448	
Baseline	Frigidaire	Frigidaire	FRT21C5A	20.5	15.3	5.3	23.8	433.2	509	77
Energy Star	Frigidaire	Frigidaire	FRT21HC5D	20.6	15.3	5.3	23.8	433.2	432	
Baseline	Whirlpool	Whirlpool	ET1MHKXM	21.0	14.6	6.4	25.0	443.1	514	71
Energy Star	Whirlpool	Whirlpool	ET1MTEXM	21.0	14.5	6.5	25.1	443.6	443	
Baseline		Kenmore	74192	20.6	15.4	5.3	23.9	434.1	509	77
Energy Star		Kenmore	74172	20.6	15.4	5.3	23.9	434.1	432	
Baseline	Whirlpool	Whirlpool	ET8MHKXM	18.2	13.2	5.0	21.4	412.4	484	72
Energy Star	Whirlpool	Whirlpool	ET8FTEXM	18.2	13.2	5.0	21.4	412.4	412	
Baseline	GE	GE	GTS18KBPWW	17.9	12.9	5.0	21.0	409.4	482	72
Energy Star	GE	GE	GTH18BRWW	17.9	12.9	5.0	21.0	409.4	410	
Baseline	GE	GE	GTR16BBSRWW	15.7	11.6	4.1	18.3	386.6	455.0	69
Energy Star	GE	GE	GTH16BBSLWW	15.7	11.4	4.1	18.1	385.6	386.0	
Baseline	GE	GE	GTR15BBR	14.9	10.8	4.1	17.5	380.0	447	67
Energy Star	GE	GE	GTH15BBR	14.9	10.7	4.1	17.4	379.4	380	

Table C-1. Top-Mount Refrigerator-Freezer Matched Pairs (cont.)

Manufacturer and Model Data				Retail Price Data							
				Manufacturer		Sears		Lowes		Home Depot	
Category	Manufacturer	Brand	Model Number	MSRP	Delta	Price	Delta	Price	Delta	Price	Delta
Baseline	GE	GE	GTS22KBPWW	$799.00		$649.88		$799.00		$729.00	
Energy Star	GE	GE	GTH22KBRWW	$849.00	$50.00	Not Listed		$849.00	$50.00	$759.00	$30.00
Baseline	Frigidaire	Frigidaire	FRT21C5A	$449.00		Not Listed		Not Listed		Not Listed	
Energy Star	Frigidaire	Frigidaire	FRT21HC5D	$549.00	$100.00	Not Listed		Not Listed		Not Listed	
Baseline	Whirlpool	Whirlpool	ET1MHKXM	$599.00		Not Listed		$577.00		Not Listed	
Energy Star	Whirlpool	Whirlpool	ET1MTEXM	$759.00	$160.00	Not Listed		$727.00	$150.00	Not Listed	
Baseline		Kenmore	74192	$499.98		$499.98		Not listed		Not Listed	
Energy Star		Kenmore	74172	$679.99	$180.01	$549.88	$49.90	Not listed		Not Listed	
Baseline	Whirlpool	Whirlpool	ET8MHKXM	$549.00		Not Listed		$527.00		Not Listed	
Energy Star	Whirlpool	Whirlpool	ET8FTEXM	$599.00	$50.00	$569.99		$583.12	$56.12	Not Listed	
Baseline	GE	GE	GTS18KBPWW	$709.00		649.9		647.0		629.0	
Energy Star	GE	GE	GTH18BRWW	$729.00	$20.00	Not Listed		Not Listed		Not Listed	
Baseline	GE	GE	GTR16BBSRWW	$579.00		Not Listed		Not Listed		Not Listed	
Energy Star	GE	GE	GTH16BBSLWW	$609.00	$30.00	Not Listed		Not Listed		Not Listed	
Baseline	GE	GE	GTR15BBR	$579.00		$549.99		Not Listed		$499.00	
Energy Star	GE	GE	GTH15BBR	$609.00	$30.00	$549.99	$0.00	Not Listed		Not Listed	

Table C-1. Top-Mount Refrigerator-Freezer Matched Pairs (cont.)

Manufacturer and Model Data				Retail Price Data									
				Howards		AJ Madison							
Category	Manufacturer	Brand	Model Number	Price	Delta	Price		Price	Delta	Price	Delta	Price	Delta
Baseline	GE	GE	GTS22KBPWW	Not Listed		$649.00		Not Listed		Not Listed		Not Listed	
Energy Star	GE	GE	GTH22KBRWW	Not Listed		$679.00	$30.00	$672.94		$649.00		Not Listed	
Baseline	Frigidaire	Frigidaire	FRT21C5A	$426.00		$479.00		$430.59		Not Listed		$419.00	
Energy Star	Frigidaire	Frigidaire	FRT21HC5D	$521.00	$95.00	Not Listed		Not Listed		Not Listed		Not Listed	
Baseline	Whirlpool	Whirlpool	ET1MHKXM	$599.00		$529.00		$556.25		$529.00		$449.00	
Energy Star	Whirlpool	Whirlpool	ET1MTEXM	$599.00	$0.00	$629.00	$100.00	$600.00	$43.75	$649.00	$120.00	$529.00	$80.00
Baseline		Kenmore	74192	Not Listed		Not Listed		Not Listed		Not Listed		Not Listed	
Energy Star		Kenmore	74172	Not Listed		Not Listed		Not Listed		Not Listed		Not Listed	
Baseline	Whirlpool	Whirlpool	ET8MHKXM	$499.00		$489.00		$530.00		$489.00		$429.00	
Energy Star	Whirlpool	Whirlpool	ET8FTEXM	$499.00	$0.00	$549.00	$60.00	$561.25	$31.25	$549.00	$60.00	$479.00	$50.00
Baseline	GE	GE	GTS18KBPWW	Not Listed		Not Listed		$627.50		$649.00			
Energy Star	GE	GE	GTH18BRWW	Not Listed		Not Listed		$652.50	$25.00	Not Listed			
Baseline	GE	GE	GTR16BBSRWW	Not Listed		Not Listed		Not Listed		Not Listed		Not Listed	
Energy Star	GE	GE	GTH16BBSLWW	Not Listed		Not Listed		Not Listed		Not Listed		Not Listed	
Baseline	GE	GE	GTR15BBR	Not Listed		Not Listed		Not Listed		Not Listed		Not Listed	
Energy Star	GE	GE	GTH15BBR	Not Listed		Not Listed		Not Listed		Not Listed		Not Listed	

Table C-1. Top-Mount Refrigerator-Freezer Matched Pairs (cont.)

Manufacturer and Model Data				Features								
					Ice Maker			Shelves: Fresh Food		Shelves: Freezer		
Category	Manufacturer	Brand	Model Number	TTD ice	None	Installed	Optional or field installable	type	number	type	number of	Special features
Baseline	GE	GE	GTS22KBPWW	n			x	glass	4	wire	1	
Energy Star	GE	GE	GTH22KBRWW	n			x	glass	4	wire	1	
Baseline	Frigidaire	Frigidaire	FRT21C5A	n	x			wire	2	wire	2	
Energy Star	Frigidaire	Frigidaire	FRT21HC5D	n	x			wire	2	wire	1	
Baseline	Whirlpool	Whirlpool	ET1MHKXM	n			x	glass	3	glass	1	
Energy Star	Whirlpool	Whirlpool	ET1MTEXM	n			x	glass	3	glass	1	has dual cooling
Baseline		Kenmore	74192	n		x		glass	3	wire	1	
Energy Star		Kenmore	74172	n		x		glass	5	wire	1	humidity controlled crispers
Baseline	Whirlpool	Whirlpool	ET8MHKXM	n			x	glass	3		1	
Energy Star	Whirlpool	Whirlpool	ET8FTEXM	n			x	glass	4		1	has dual cooling
Baseline	GE	GE	GTS18KBPWW	n			x	glass	4	wire	1	
Energy Star	GE	GE	GTH18BRWW	n			x	glass	4	wire	1	
Baseline	GE	GE	GTR16BBSRWW	n			x	wire	2		0	
Energy Star	GE	GE	GTH16BBSLWW	n			x	wire	2		0	
Baseline	GE	GE	GTR15BBR	n	x			wire	2		0	
Energy Star	GE	GE	GTH15BBR	n	x			wire	2		0	

Table C-2. Side-Mount Refrigerator-Freezer Matched Pairs

Manufacturer and Model Data				Volume Data (cu. ft.)						
Category	Manufacturer	Brand	Model Number	Capacity	Fresh Food Capacity	Freezer Capacity	Adjusted Volume	Energy Star Threshold	Annual Energy Use	Delta Energy Use
Baseline	GE	GE Profile	PSI23NGPWW	22.6	14.4	8.2	27.8	583.9	686	102
Energy Star	GE	GE Profile	PSH23PGRWW	22.6	14.1	8.5	28.0	585.2	584	
Baseline	GE	GE	GSS25KGPWW	24.9	15.4	9.6	31.0	611.1	715	105
Energy Star	GE	GE	GSH25KGRWW	25.0	15.4	9.6	31.0	611.1	610	
Baseline	Frigidaire	Frigidaire	GLRS267ZD	25.7	16.5	9.5	31.9	619.3	727	109
Energy Star	Frigidaire	Frigidaire	GLHS268ZD	26.0	16.5	9.5	31.9	619.4	618	
Baseline	Maytag	Amana	ASD2622HRW	25.6	15.8	9.8	31.8	617.9	705	88
Energy Star	Maytag	Amana	ASD2624HEW	25.6	15.8	9.8	31.8	617.9	617	

Table C-2. Side-Mount Refrigerator-Freezer Matched Pairs (cont.)

Manufacturer and Model Data				Retail Price Data							
				Manufacturer		Sears		Lowes		Home Depot	
Category	Manufacturer	Brand	Model Number	MSRP	Delta	Price	Delta	Price	Delta	Price	Delta
Baseline	GE	GE Profile	PSI23NGPWW	$2,599.00		$2,374.99		$2,497.00		Not Listed	
Energy Star	GE	GE Profile	PSH23PGRWW	$2,849.00	$250.00	Not Listed		Not Listed		Not Listed	
Baseline	GE	GE	GSS25KGPWW	$1,199.00		$1,092.49		Not Listed		Not Listed	
Energy Star	GE	GE	GSH25KGRWW	$1,249.00	$50.00	Not Listed		$1,047.00		$999.00	
Baseline	Frigidaire	Frigidaire	GLRS267ZD	$1,099.00		Not Listed		$1,147.00		Not Listed	
Energy Star	Frigidaire	Frigidaire	GLHS268ZD	$1,199.00	$100.00	Not Listed		$1,287.01	$140.01	Not Listed	
Baseline	Maytag	Amana	ASD2622HRW	$1,139.00		$999.99		Not Listed		Not Listed	
Energy Star	Maytag	Amana	ASD2624HEW	$1,239.00	$100.00	Not Listed		Not Listed		Not Listed	

Table C-2. Side-Mount Refrigerator-Freezer Matched Pairs (cont.)

Manufacturer and Model Data				Retail Price Data									
				Howards		AJ Madison							
Category	Manufacturer	Brand	Model Number	Price	Delta	Price	Delta	Price	Delta	Price	Delta	Price	Delta
Baseline	GE	GE Profile	PSI23NGPWW	$2,499.00		Not Listed		Not Listed		Not Listed		Not Listed	
Energy Star	GE	GE Profile	PSH23PGRWW	Not Listed		Not Listed		Not Listed		Not Listed		Not Listed	
Baseline	GE	GE	GSS25KGPWW	Not Listed		Not Listed		$1,269.00		Not Listed		Not Listed	
Energy Star	GE	GE	GSH25KGRWW	Not Listed		Not Listed		$1,266.25	$-2.75	Not Listed		Not Listed	
Baseline	Frigidaire	Frigidaire	GLRS267ZD	Not Listed		Not Listed		$955.29		$1,029.00		Not Listed	
Energy Star	Frigidaire	Frigidaire	GLHS268ZD	$1,099.00		$1,189.00		$1,058.82	$103.53	$1,189.00	$160.00	Not Listed	
Baseline	Maytag	Amana	ASD2622HRW	Not Listed		$869.00		$900.00		$869.00		$849.00	
Energy Star	Maytag	Amana	ASD2624HEW	Not Listed		$919.00	$50.00	$954.87	$54.87	$919.00	$50.00	$905.00	$56.00

Table C-2. Side-Mount Refrigerator-Freezer Matched Pairs (cont.)

Manufacturer and Model Data				Features								
					Ice Maker				Shelves: Fresh Food		Shelves: Freezer	
Category	Manufacturer	Brand	Model Number	TTD ice	None	Installed	Optional or field installable	Water Filter	type	number	type	number
Baseline	GE	GE Profile	PSI23NGPWW	y		x			glass	3	wire	2
Energy Star	GE	GE Profile	PSH23PGRWW	y		x			glass	3		2
Baseline	GE	GE	GSS25KGPWW	y		x		x	glass	3		4
Energy Star	GE	GE	GSH25KGRWW	y		x		x	glass	3		4
Baseline	Frigidaire	Frigidaire	GLRS267ZD	y		x		x	glass	3	glass	2
Energy Star	Frigidaire	Frigidaire	GLHS268ZD	y		x		x	glass	3	glass	2
Baseline	Maytag	Amana	ASD2622HRW	y		x		x	glass	3		
Energy Star	Maytag	Amana*	ASD2624HEW	y		x		x	glass	3		

APPENDIX D. MANUFACTURER INTERVIEW GUIDE

BACKGROUND: PRIORITY SETTING CRITERIA

1. Energy savings potential
2. Potential economic benefits / burdens
3. Potential environmental or energy security benefits
4. Applicable deadlines for rulemakings
5. Incremental DOE resources required to complete rulemaking process
6. Evidence of market-driven or voluntary efficiency improvements
7. Status of required changes to test procedures
8. Impact of potential regulation on product innovation
9. Fuel neutrality
10. Impact on peak demand for electricity
11. Impact of potential regulation on small businesses
12. Cumulative regulative burden on products, related products manufactured by the same manufacturers

DESIGN FOR ENERGY IMPROVEMENT INFORMATION REQUEST

We want to confirm information on the cost impact of increasing refrigerator efficiency by understanding the design options involved in the efficiency improvement. We expect a significant, but not large, level of design change associated with bringing current refrigerator model lines up to Energy Star level. It is our expectation that Energy Star level can be achieved with some insulation thickness increase and use of more efficient refrigeration system components. Questions are as follows.

1. What design changes are generally required to convert a typical 2001-compliant Top-Mount refrigerator to Energy Star level? Are the set of required design changes different for Side-by-Side models?
2. What additional design changes would be required to achieve an additional 10% energy reduction, possibly the level of a future Energy Star?

3. Are “matched pair” models instructive for understanding these design differences? We are defining matched pairs as a pair of models that are effectively the same units except for energy: the models have nearly identical internal volume, identical external dimensions and features, but one model meets the 2001 Energy Standard and the other meets Energy Star. Design differences between such units may be instructive in illustrating the differences between 2001-compliant units and current Energy Star units. Are such data available for Top-Mount and Side-by-Side model pairs?

4. What are the fundamental differences between required design changes that make the cost increment much higher for some product class/sizes than others?

MANUFACTURER IMPACT ANALYSIS TOPICS

1 Key Issues

1.1 What are the key issues for your company regarding a possible future residential refrigerator rulemaking?

2 Conversion Costs

2.1 What level of capital expenditure and product conversion costs would you anticipate to make at higher standard levels? Please describe what they are and provide your best estimate of their respective magnitudes.

2.2 2.2 How would the imposition of new energy efficiency standards affect capacity utilization and manufacturing assets at your domestic production facilities? Would a new standard result in stranded capital assets? Would any facilities be closed or downsized? Added or upgraded?

2.3 How might a new standard impact product innovation?

3 Product Mix and Profitability

3.1 How would your company’s product mix and marketing strategy change with changes in the efficiency standard?

3.2 Would the current percentage of shipments at Energy Star be the same under a new "15% more-efficient" standard?

3.3 What distribution channels are used from the manufacturer to the retail outlet? What is the share of product going through each distribution channel?

3.4 Generally how would new refrigerator standards impact your customer mix, distribution channels and corresponding profit margins?

3.5 How might a new standard impact the Energy Star program and consequently your firm?

3.6 In reference to the "summary data tables" provided by AHAM, for each product class, what is the approximate percentage of shipments (i.e., market share) for each refrigerator size?

4 Exports, Foreign Competition, and Outsourcing

4.1 Would new standards change your projected export sales?

4.2 Would new standards have an impact on the portion of the domestic market served by foreign competition?

4.3 Would standards impact your decisions regarding domestic production levels? How would domestic employment levels change under new energy efficiency standards?

5 Market Shares and Industry Consolidation

5.1 In the absence of new standards, do you expect any industry consolidation?

5.2 How would new standards affect your ability to compete?

5.3 Could new standards disproportionately advance or harm the competitive positions of some firms?

5.4 Are there concerns over intellectual property?

5.5 Could new standards result in disproportionate economic or performance penalties for particular consumer/user subgroups?

5.6 Beyond price and energy efficiency, could new standards result in products that will be more or less desirable to consumers due to changes in product functionality, utility or other features?

6 Cumulative Regulatory Burden

6.1 Are there recent or impending regulations on refrigerators or other products that impose a cumulative burden on the industry?

What is the total expected impact of those other regulations?