CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

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CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

3.1 INTRODUCTION

This chapter provides a profile of the residential microwave ovens in the United States. The U.S. Department of Energy (DOE) developed the market and technology assessment presented in this chapter primarily from publicly available information. This assessment is helpful in identifying the major manufacturers and their product characteristics, which form the basis for the engineering and the life-cycle cost (LCC) analyses. Present and past industry structure and industry financial information help DOE in the process of conducting the manufacturer impact analysis.

3.2 PRODUCT DEFINITIONS

DOE defines "microwave oven" under the Energy Policy and Conservation Act (EPCA) of 1975, Pub. L. 94-163, (42 United States Code (U.S.C.) 6291–6309) as "a class of kitchen ranges and ovens which is a household cooking appliance consisting of a compartment designed to cook or heat food by means of microwave energy." (10 Code of Federal Regulations (CFR) 430.2)

3.3 PRODUCT CLASSES

DOE intends to separate microwave ovens into product classes. Because DOE will formulate a separate energy conservation standard for each product class, the criteria for separation into different classes are: (1) type of energy used, and (2) capacity or other performance-related features such as those that provide utility to the consumer or others deemed appropriate by the Secretary that would justify the establishment of a separate energy conservation standard. (42 U.S.C. 6295 (q))

In the notice of proposed rulemaking (NOPR) published on October 17, 2008 (hereafter the "October 2008 NOPR"), DOE proposed a single product class for microwave ovens. DOE stated this product class encompasses microwave ovens with and without browning elements, but does not include microwave ovens that incorporate convection systems. 73 FR 62034, 62048.

DOE reassessed what products would be considered microwave ovens under the regulatory definition, and whether multiple product classes would be appropriate. As discussed in the microwave oven test procedure final rule which was published in the *Federal Register* on March 9, 2011 (hereafter, the "March 2011 TP Interim Final Rule"), DOE stated that microwave ovens with or without thermal elements would be considered covered products under the definition provided in 10 CFR 430.2. In addition, DOE stated that combination microwave ovens (*i.e.*, microwave ovens that incorporate convection features and possibly other means of cooking) would also be considered covered products under the regulatory definition in 10 CFR 430.2 because they are capable of cooking or heating food by means of microwave energy. DOE stated, based on its preliminary analysis, it believes that the general standby mode and off mode operation for combination microwave ovens does not differ from that of microwave-only units and microwave ovens with thermal elements only. The standby mode operation for combination microwave ovens, as with other types of microwave ovens, consists of an energized display with a clock. As a result, DOE amended the microwave oven test procedure to require that the same standby mode and off mode testing methods be used for all microwave ovens. 76 FR 12825, 12828–30 (Mar. 9, 2011).

In order to determine whether specific types of microwave ovens should be separated into different product classes, DOE investigated whether there are any performance related features that would justify the establishment of a separate energy conservation standard. As discussed in the October 2008 NOPR, DOE tested a sample of 32 countertop microwave-only units and measured standby power ranging from 1.2 watts (W) to 5.8 W. 73 FR 62034, 62042 (Oct. 17, 2008). None of these units was capable of operation in off mode, nor is DOE aware of any other current microwave ovens capable of such operation. DOE noted that standby power consumption for microwave-only units largely depended on the presence of a cooking sensor, the display technology, the power supply and control board, and implementation of a power-down feature. With regards to display technologies, DOE noted that microwave-only units incorporated Light Emitting Diode (LED) displays, Liquid Crystal Displays (LCDs), and Vacuum Fluorescent Displays (VFDs).

DOE conducted a survey of over-the-range microwave-only units available on the U.S. market. DOE determined that the display technologies used are similar to those used in countertop microwave-only units (*i.e.*, LED displays, LCDs, and VFDs). DOE's market survey revealed that multiple over-the-range microwave-only units incorporate both LED displays and LCDs. DOE research suggests that LED displays and LCDs in both countertop and over-the-range microwave-only products offer acceptable consumer utility features, including brightness, viewing angle, and ability to display complex characters. DOE also conducted in-store standby mode testing on a limited sample of over-the-range microwave-only units which showed similar standby power consumption as countertop microwave-only units. For these reasons, DOE tentatively concludes that over-the-range microwave-only units would not warrant a separate product class according to the criteria put forth by EPCA. (42 U.S.C. 6295(q)). DOE understands that over-the-range microwave-only units may have additional components that are energized during active mode operation (*i.e.*, exhaust fan motors). However, DOE's testing showed that the presence of such features did not increase the standby power consumption to warrant establishing a separate product class.

DOE also conducted standby power testing on a sample of 13 representative combination microwave ovens, including 5 countertop combination microwave ovens, 6 over-the-range combination microwave ovens, and 2 built-in combination microwave ovens. DOE's testing showed that the countertop combination microwave ovens use similar display technologies as countertop microwave-only units (*i.e.*, LED displays, LCDs, and VFDs), and had standby power consumption ranging from 1.2 W to 4.7 W, which is similar to the standby power consumption for countertop microwave-only units. As a result, DOE tentatively concludes that countertop combination microwave ovens would not warrant a product class separate from microwave-only ovens. DOE's testing of built-in and over-the-range combination microwave ovens showed that the standby power consumption for these products ranged from 4.1 W to 8.8 W, which is higher than the standby power consumption for other microwave oven product types (*i.e.*, countertop microwave-only, over-the-range microwave-only, and countertop combination microwave ovens). DOE's reverse-engineering analysis suggests that the additional features in built-in and over-the-range combination microwave ovens required to handle the thermal loads associated with their installation and to provide consumer utility, such as additional exhaust fan motors, convection fan motors and heaters, and additional lights, require a significant number of additional relays on the control board, and thus require a larger power supply for the control of such relays. While the relays themselves do not consume power in standby mode, they increase the total power supply requirements of the control board and thus increase the standby losses of the power supply. As a result, DOE believes that a separate product class should be established for built-in and over-the-range combination microwave ovens. DOE recognizes that built-in and over-the-range microwave-only units may similarly require some additional relays for exhaust fans and lights, and that countertop combination microwave ovens would require some additional relays for convection fans and heaters. However, DOE's product testing and reverse-engineering analyses indicated that these product types use similar-sized power supplies as those found in countertop microwave-only units, and as a result would not warrant a separate product class from countertop microwave-only units. Details of standby power testing for the determination of product classes are presented in chapter 5 of this technical support document (TSD).

In summary, DOE proposes to establish the following two product classes for microwave ovens:

Table 3.3.1 Microwave Oven Product Classes

Product Class
1. Microwave-Only Ovens and Countertop Combination Microwave Ovens
2. Built-in and Over-the-Range Combination Microwave Ovens

DOE determined that separate product classes for the purposes of setting energy conservation standards addressing standby mode and off mode energy use are warranted on the basis of different standby power performance. DOE did not evaluate whether the same product class distinction would also be appropriate for any active mode energy use standards because DOE eliminated the regulatory provisions establishing the cooking efficiency test procedure for microwave ovens in a final rule published in the *Federal Register* on July 22, 2010 (hereafter, the "July 2010 TP Final Rule"). 75 FR 42579. If DOE adopts amendments to the microwave oven test procedure to include provisions for measuring active mode cooking efficiency, DOE may reevaluate these product classes as part of a future microwave oven energy conservation standards rulemaking. At that time, DOE may consider dividing countertop combination microwave ovens and over-the-range/built-in microwave-only units into separate product classes to account for the energy performance of heating components other than the microwave portion.

3.4 PRODUCT TEST PROCEDURES

DOE originally established test procedures for microwave ovens to determine energy efficiency and annual energy use as the basis for representation and determination of compliance with energy conservation standards. DOE established test procedures for microwave ovens through the rulemaking process.

Historically, DOE's test procedures for microwave ovens appeared at appendix I to subpart B of Title 10 of the CFR. Those test procedures were part of a May 10, 1978, final rule that first established test procedures for conventional ranges, cooktops, and ovens (including microwave ovens). 43 FR 20108. DOE revised its test procedures for cooking products to measure their efficiency and energy use more accurately, publishing a final rule on October 3, 1997. 62 FR 51976. The revised microwave oven test procedure incorporated portions of the International Electrotechnical Commission (IEC) Standard 705-1998 and Amendment 2-1993 (IEC Standard 705), *Methods for Measuring the Performance of Microwave Ovens for Households and Similar Purposes*. It measured microwave oven cooking efficiency, but did not address energy use in the standby mode or off modes. *Id.*

Section 310 of the Energy Independence and Security Act of 2007 (EISA 2007) (Pub. L. No. 110-140) amends Section 325 of the EPCA to require that that the test procedures for microwave ovens be amended to include measurement of standby mode and off mode power, taking into consideration the most current version of IEC Standard 62301 *Household electrical appliances – Measurement of standby power* (IEC Standard 62301) and IEC Standard 62087 *Methods of measurement for the power consumption of audio, video and related equipment*.[a] EPCA, as amended by the EISA 2007, also states that the final rule for this test procedure shall be published no later than March 31, 2011. (42 U.S.C. 6295(gg))

DOE published a test procedure NOPR on October 17, 2008 (hereafter referred to as the "October 2008 TP NOPR"), in which it proposed to incorporate provisions from IEC Standard 62301 First Edition into the DOE microwave oven test procedure, as well as language to clarify application of these provisions for measuring standby mode and off mode power in microwave ovens. The October 2008 TP NOPR also proposed correcting a technical error in the calculation of microwave test cooking energy output. 73 FR 62134 (Oct. 17, 2008). DOE held a public meeting on the proposed rulemaking on November 14, 2008. DOE received comments from interested parties both in written responses to the October 2008 NOPR and at the November 2008 Public Meeting.

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[a] IEC 62087 does not cover any products for this rulemaking, and therefore was not considered.

After considering stakeholder comments and additional information, DOE issued a supplemental NOPR (SNOPR) on July 22, 2010 (hereafter referred to as the July 2010 TP SNOPR) for the test procedure for measuring microwave oven standby mode and off mode power consumption. 75 FR 42612 (Jul. 22, 2010). In that SNOPR, DOE proposed adopting definitions of modes based on relevant provisions from IEC Standard 62301 Second Edition, Committee Draft for Vote (IEC Standard 62301 CDV), as well as language to clarify application of those provisions for measuring microwave oven standby mode and off mode power consumption. *Id*.

In response to the October 2008 TP NOPR, DOE received comments from interested parties regarding the accuracy and repeatability of the existing DOE microwave oven test procedure for measuring cooking efficiency. Because of issues DOE identified with using its existing microwave oven test procedure, including the large test-to-test variation in cooking efficiency measurements, and because DOE is unaware of any test procedures that have been developed that address the concerns with the DOE microwave oven cooking efficiency test procedure raised by these interested parties, DOE published the July 2010 TP Final Rule repealing the provisions in the existing microwave oven test procedure relating to the measurement of cooking efficiency and energy factor (EF). 75 FR 42579 (Jul. 22, 2010). Therefore, the requirement to integrate energy consumption in standby mode and off mode into an overall energy descriptor does not apply. DOE also published a notice in the *Federal Register* on July 22, 2010, announcing a public meeting to consider developing a new test procedure for active mode energy consumption of microwave ovens, and DOE will consider the statutory requirement to integrate the test procedures for standby and off mode as any active mode test procedures are developed. 75 FR 42611.

DOE held a public meeting on September 16, 2010, to receive oral comments on the July 2010 TP SNOPR, and also sought and received written comments. DOE also invited inputs on microwave active mode test procedures for a potential new test procedure rulemaking.

After consideration of these comments, DOE published the March 2011 TP Interim Final Rule addressing microwave oven standby mode and off mode power. 76 FR 12825 (Mar. 9, 2011). In that final rule, DOE adopted the provisions for the measurement of standby mode and off mode power use for both products that were proposed in the July 2010 TP SNOPR. In addition, DOE also adopted provisions to define the test duration for cases in which the measured power is not stable (*i.e.*, varies over a cycle), recognizing that the power consumption of microwave oven displays can vary based on the displayed clock time. 76 FR 12825, 12837–40 (Mar. 9, 2011).

3.5 MANUFACTURER TRADE GROUPS

DOE recognizes the importance of trade groups in disseminating information and promoting the interests of the industry that they support. To gain insight into the residential microwave oven industry, DOE researched various associations available to manufacturers, suppliers, and users of such equipment. DOE also used the member lists of these groups in the construction of an exhaustive database containing domestic manufacturers.

DOE identified the Association of Home Appliance Manufacturers (AHAM) as a trade group that supports the microwave oven industry, AHAM,[b] formed in 1967, aims to enhance the value of the home appliance industry through leadership, public education and advocacy. AHAM provides services to its members including government relations; certification programs for room air conditioners, dehumidifiers and room air cleaners; an active communications program; and technical services and research. In addition, AHAM conducts other market and consumer research studies and publishes a biennial *Fact Book*. AHAM also develops and maintains technical standards for various appliances to provide uniform, repeatable procedures for measuring specific product characteristics and performance features.

3.6 MANUFACTURER INFORMATION

The following section details information regarding domestic manufacturers of residential microwave ovens, including estimated market shares (section 3.6.1), industry mergers and acquisitions (section 3.6.2), potential small business impacts (section 3.6.3), and product distribution channels (section 3.6.4).

3.6.1 Manufacturers and Market Shares

Using publicly available data (*e.g. Appliance Magazine* and market assessments done by third parties), DOE estimates the market shares for domestic manufacturers of each of the products contained in this standards rulemaking. Manufacturers may offer multiple brand names. Some of the brand names come from independent appliance manufacturers which have been acquired over time, and domestic manufacturers may put their brand on a product manufactured overseas. Companies included in this analysis may also be off-shore manufacturers that maintain a significant domestic presence via a U.S. entity.

The microwave oven market differs from the rest of the domestic cooking product market in that many of the manufacturers are foreign-owned companies with manufacturing facilities outside of the United States, and many of the domestic appliance manufacturers rebrand foreign-manufactured products. Table 3.6.1 illustrates the 2008 market shares for the U.S. microwave oven market. Microwave oven manufacturers with facilities inside the United States include Whirlpool, the Sharp Electronics Corporation (Sharp), Sub-Zero, Summit, and Viking. Figure 3.6.1 lists microwave manufacturers active in the domestic market.

[b] For more information visit http://www.aham.org.

Table 3.6.1 Major and Other Microwave Oven Manufacturers

Major Manufacturers	Other Manufacturers
LG Electronics, Inc. (LG)	Daewoo Electronics Company, Ltd. (Daewoo)
Sharp	Panasonic Corporation of America (Panasonic)
Samsung Electronics America, Inc. (Samsung)	Whirlpool
	Guangdong Galanz Enterprise Co., Ltd. (Galanz)
	GD Midea Microwave Oven Mfg. Co., Ltd. (Midea)
	Sanyo
	Sub-Zero
	Summit
	Viking

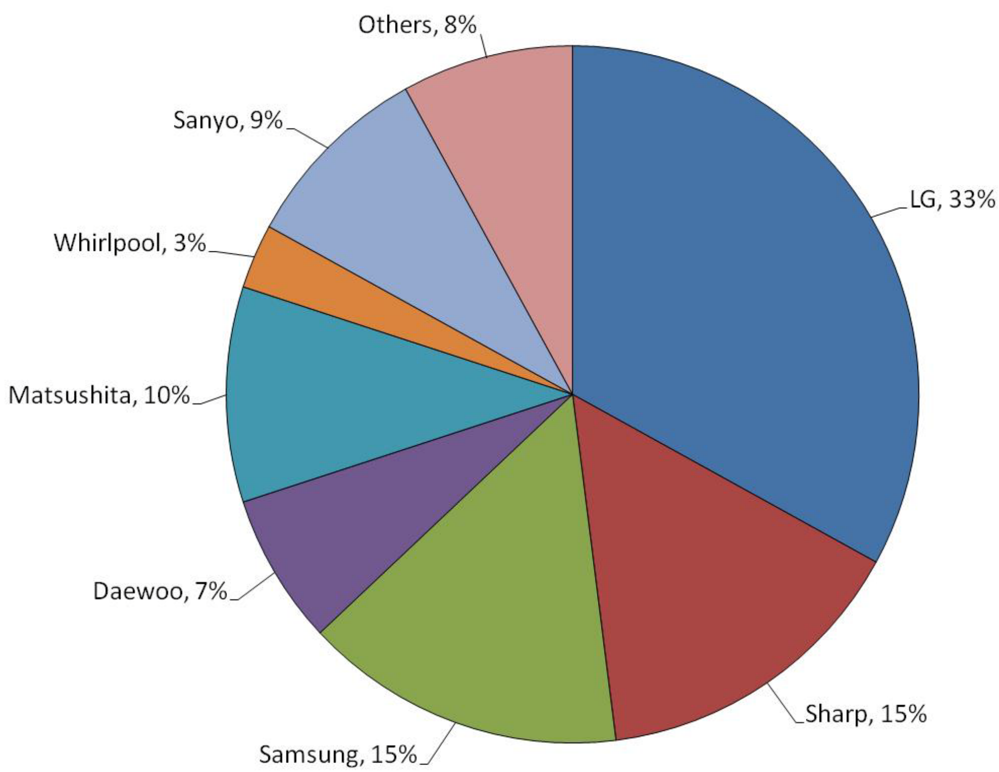

Figure 3.6.1 2008 Market Shares for the Domestic Microwave Oven Market[1]

3.6.2 Mergers and Acquisitions

Due to mergers and acquisitions, the home appliance industry continues to consolidate. While this phenomenon varies from product to product within the industry, the large market shares of a few companies provide evidence in support of this characterization.

According to the January 2010 issue of *Appliance Magazine*, three manufacturers comprise 85 percent of the core appliance market share. "Core appliances" include dishwashers, clothes dryers, freezers, ranges, refrigerators, and clothes washers. Table 3.6.2 lists these core appliance manufacturers, and Figure 3.6.2 illustrates the breakdown of 2008 market shares in the core appliance category.

Table 3.6.2 Core Appliance Manufacturers

Core Appliance Manufacturers
Whirlpool
GE
Frigidaire

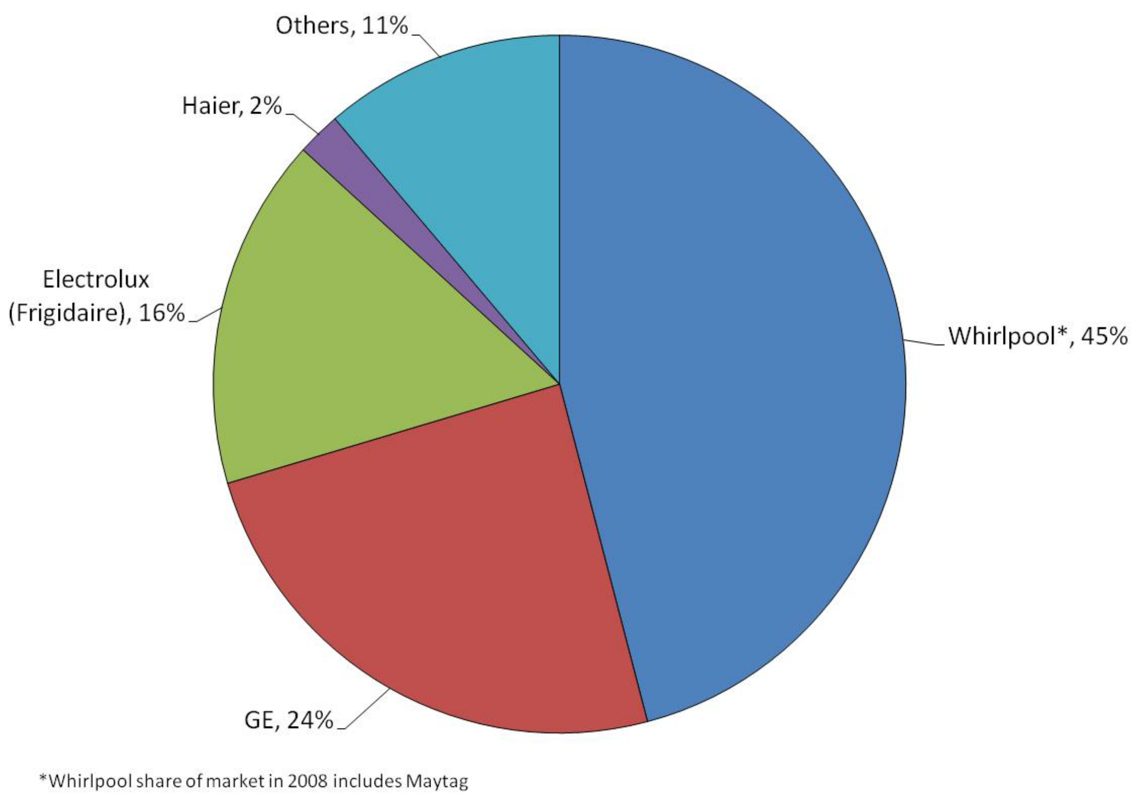

Figure 3.6.2 2008 Core Appliance Market Shares[2]

On August 22, 2005, Whirlpool, headquartered in Benton Harbor, Michigan, and Maytag, based in Newton, Iowa, announced plans to merge in a deal worth \$2.7 billion.[3] Maytag shareholders approved the merger on December 22, 2005. Shortly after announcing the merger, Whirlpool submitted a pre-merger notification to the U.S. Department of Justice (DOJ). The DOJ Antitrust Division initiated an investigation, scheduled to end February 27, 2006, into the effects of the merger, including potential lessening of competition or the creation of a monopoly. Following this initial review, the DOJ asked for additional materials from each company and extended the review to March 30, 2006.

Opponents of the merger asserted that the combined companies would control as much as 70 percent of the residential laundry market and as much as 50 percent of the residential dishwasher market.[4] Whirlpool claimed that their large potential residential laundry market share was skewed because the company produces washing machines for Sears, which sells them under their Kenmore in-house brand. Whirlpool went on to say that they must periodically bid with other manufacturers to keep the Kenmore contract and that Sears controls the pricing of the Kenmore units.[5]

In early January 2006, U.S. Senator Tom Harkin and U.S. Representative Leonard Boswell, both of Iowa, called upon the DOJ to block the merger, claiming it would give Whirlpool an unfair advantage in the home appliance industry. The Congressmen wrote, that if the DOJ does not block the deal, the agency should at least "require that Whirlpool divest the washer and dryer portions of Maytag to a viable purchaser who will have the financial capability and desire to continue to operate that business."[6]

On March 29, 2006, DOJ closed its investigation and approved the merger. DOJ claims "that the proposed transaction is not likely to reduce competition substantially. The combination of strong rival suppliers with the ability to expand sales significantly and large cost savings and other efficiencies that Whirlpool appears likely to achieve indicates that this transaction is not likely to harm consumer welfare."[7]

The DOJ Antitrust Division focused its investigation on residential laundry, although it considered impacts across all products offered by the two companies. DOJ determined that the merger would not give Whirlpool excessive market power in the sale of its products and that any attempt to raise prices would likely be unsuccessful. In support of this claim, DOJ noted that (1) other U.S. brands, including Kenmore, GE, and Frigidaire, are well established; (2) foreign manufacturers, including LG and Samsung, are gaining market share; (3) existing U.S. manufacturers are below production capacity; (4) the large home appliance retailers have alternatives available to resist price increase attempts; and (5) Whirlpool and Maytag substantiated large cost savings and other efficiencies that would benefit consumers.[8]

Whirlpool and Maytag completed the merger on March 31, 2006. This large merger follows several other mergers and acquisitions in the home appliance industry. For example, Maytag acquired Jenn-Air Corporation (Jenn-Air) in 1982, Magic Chef, Inc. (Magic Chef) in 1986, and Amana Appliances (Amana) in 2001. Whirlpool acquired the KitchenAid division of Hobart Corporation (KitchenAid) in 1986. White Consolidated Industries (WCI) acquired the Frigidaire division of General Motors Corporation in 1979, and AB Electrolux acquired WCI (and therefore Frigidaire) in 1986.

3.6.3 Small Business Impacts

DOE considers the possibility of small businesses being impacted by the promulgation of energy conservation standards for residential cooking products. At this time, DOE is not aware of any small microwave oven manufacturers, defined by the Small Business Association (SBA) as having 750 employees or fewer, who produce products that fall under this rulemaking and who therefore would be impacted by a minimum efficiency standard. For further information, see chapter 12 of the TSD.

3.6.4 Distribution Channels

Understanding the distribution channels of products covered by this rulemaking is an important facet of the market assessment. DOE gathered information regarding the distribution channels for residential cooking products from publicly available sources. This section contains distribution channel information for residential appliances.

The distribution chain for residential appliances, including microwave ovens, differs from commercial products, as the majority of consumers purchase their appliances directly from retailers. These retailers include: (1) home improvement, appliance, and department stores; (2) Internet retailers; (3) membership warehouse clubs; and (4) kitchen remodelers. The AHAM *Fact Book 2005* reports that home improvement stores claim nearly one out of every four dollars spent on appliances.[9]

Home appliance retailers generally obtain products directly from manufacturers. The AHAM *Fact Book 2003* shows that over 93 percent of residential appliances are distributed from the manufacturer directly to a retailer.[10]

3.7 REGULATORY PROGRAMS

The following section details current regulatory programs mandating energy conservation standards for residential cooking products. Section 3.7.1 discusses Federal energy conservation standards and section 3.7.2 reviews upcoming standards under EISA 2007. In addition, section 3.7.3 reviews foreign standby power regulatory programs that may impact the companies servicing the North American market.

3.7.1 Federal Energy Conservation Standards

The National Appliance Energy Conservation Act of 1987 (NAECA) (42 U.S.C. 6291-6309), which amended EPCA, established prescriptive standards for kitchen ranges and ovens, but no standards were established for microwave ovens. (42 U.S.C. 6295(h)) The NAECA amendments also required DOE to conduct two cycles of rulemakings to determine whether to revise the standard. (42 U.S.C. 6295 (h)(1)–(2)) DOE undertook the first cycle of these rulemakings and issued a final rule on September 8, 1998 in which DOE found that no amended standards were justified for electric cooking products, including microwave ovens. 63 FR 48038.

DOE initiated the second cycle of energy conservation standards rulemakings for cooking products by publishing a framework document covering, in part, microwave ovens, and giving notice of a public meeting and the availability of the document. 71 FR 15059 (Mar. 27, 2006). In its subsequent advance notice of proposed rulemaking (ANOPR) concerning energy conservation standards for commercial clothes washers and residential dishwashers, dehumidifiers, and cooking products, including microwave ovens, DOE determined that energy consumption by microwave ovens in the standby mode represents a significant portion of microwave oven energy use, and that a standard regulating such energy consumption would likely have significant energy savings. 72 FR 64432, 64441–42 (Nov. 15, 2007). DOE published a NOPR for the appliance standards rulemaking on October 17, 2008, in which it tentatively concluded that a standard for microwave oven standby mode and off mode energy consumption would be technologically feasible and economically justified. 73 FR 62034. DOE received responses to the NOPR from interested parties regarding the harmonization of standards and test procedures with those of other countries and international agencies. As a result of these comments, DOE decided to consider the revised version of IEC Standard 62301 (*i.e.*, IEC Standard 62301 Second Edition) in the development of energy conservation standards for the standby mode and off mode power consumption of microwave ovens. In a final rule published on April 8, 2009 (74 FR 16040), DOE established amended standards for gas cooking products, but again found that no active mode cooking efficiency standards were justified for electric cooking products, including microwave ovens. This rulemaking completed the second cycle of rulemakings required by the NAECA amendments to EPCA. (42 U.S.C. 6295(h)(2))

3.7.2 Energy Independence and Security Act of 2007

On December 19, 2007, the President signed into law EISA 2007, which contains numerous amendments to EPCA. Section 310 of EISA 2007 amends section 325 of EPCA to require any final rule establishing or revising a standard for a covered product, adopted after July 10, 2010, shall incorporate standby mode and off mode energy use into a single amended or new standard. (42 U.S.C. 6295(gg)(3)(A)) If not feasible, the Secretary shall prescribe within the final rule a separate standard for standby mode and off mode energy consumption, if justified. (42 U.S.C. 6295(gg)(3)(B))

Off mode is defined by EPCA as "the condition in which an energy-using product – (I) is connected to a main power source; and (II) is not providing any standby or active mode function." (42 U.S.C. 6295(gg)(1)(A)(ii)) Active mode refers to the main (cooking) function, while standby is defined by EPCA as "the condition in which an energy-using product (I) is connected to a main power source; and (II) offers 1 or more of the following user-oriented or protective functions: (aa) To facilitate the activation or deactivation of other functions (including active mode) by remote switch (including remote control), internal sensor, or timer. (bb) Continuous functions, including information or status displays (including clocks) or sensor-based functions." (*Id.*; 42 U.S.C. 6295(gg)(1)(A)(iii))

On November 15, 2007 DOE published an advanced notice of proposed rulemaking (ANOPR) (hereafter the "November 2007 ANOPR") in which it stated that it was considering including standby power in the energy conservation standards and intended to initiate amendment of its test procedure to measure microwave oven standby power because: 1) energy conservation in standby mode represents a significant proportion of microwave oven annual energy consumption; and 2) the range of standby power among microwave ovens currently on the market suggests that the likely impact of a standard would be significant. 72 FR 64432. Such a test procedure change is a prerequisite to incorporate a standby power requirement as part of the energy conservation standard for microwave ovens.[c] Data obtained by DOE during testing of a representative sample of microwave ovens and from AHAM show standby power ranging from 1.1 to 5.8 W. At the Federal Energy Management Program (FEMP)-defined limit of 2 W, the resulting 17.2 kWh of annual standby energy use represents 13 percent of the estimated annual cooking energy consumption for a baseline microwave oven. DOE is unaware of any microwave ovens currently on the market in the United States that consume energy in off-mode, differentiable from standby mode. Therefore, DOE proposed for the purposes of the October 2008 NOPR to put forth standards for microwave oven standby power only, but stated it was open to consideration of off-mode standards.

As discussed above in section 3.4, the test procedure rulemaking to incorporate methods for measuring standby mode and off mode energy consumption for microwave ovens was initiated in parallel with the current rulemaking. Because DOE repealed the provisions in the existing microwave oven test procedure relating to the measurement of cooking efficiency and EF, the requirement to integrate energy consumption in standby mode and off mode into an overall energy descriptor does not apply. The absence of active mode provisions results in a *de facto* separate energy use descriptor for microwave oven standby mode and off mode energy use. Accordingly, DOE proposed amended energy conservation standards for microwave ovens based on these separate energy use descriptors.

3.7.3 Foreign Standby Power Regulatory Programs

The International Energy Agency (IEA) has raised awareness of standby power through publications, international conferences, and policy advice to governments. In 1999, the IEA developed the "1-Watt Plan," which proposed reducing standby power internationally in electronic devices and which advocates that all countries harmonize energy policies and adopt the same definition and test procedure. The IEA has advocated a 1-W requirement for all consumer electrical products (unless specifically excluded) in standby mode. The IEA also stated that IEC Standard 62301 provides an internationally sanctioned definition and test procedure for standby power, which is now widely specified and used.[d]

A number of countries have implemented regulatory approaches to standby power in microwave ovens. Australia has announced plans to implement a mandatory 1-W requirement

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[d] For more information visit http://www.iea.org/.

for all consumer electrical products by 2012, including microwave ovens.[11] The Korea Energy Management Corporation developed their "e-standby" program, which currently has a voluntary labeling program for microwave ovens with less than 1 W of standby power, and a mandatory labeling requirement for microwave ovens with standby power greater than 1 W.[12] In accordance with Japan's Top Runner Program,[e] Japanese appliance manufacturers made a voluntary declaration to reduce standby power consumption of microwave ovens without a timer as close to 0 W as possible and that of microwave ovens with a timer to 1 W or lower.[13]

The European Union (EU) passed the Ecodesign Directive in 2005 which calls for an implementing measure to reduce standby power for a specified list of energy using products, which include microwave ovens. On December 17, 2008, the Commission of the European Communities published Commission Regulation 1275/2008 implementing Ecodesign requirements for standby and off mode electric power consumption. Table 3.7.7 presents the criteria for standby and off mode power for microwave ovens, which are well in line with the IEA 1-W plan.[14]

Table 3.7.1 EU Ecodesign Requirements for Standby and Off Mode

Mode	**Maximum Power (*W*)**
Tier 1 (December 17, 2009)	
Off (no function)	1.0 W
Standby (only reactivation function)	1.0 W
Standby (information or status display plus reactivation function	2.0 W
Tier 2 (December 17, 2012)	
Off (no function)	0.5 W
Standby (only reactivation function)	0.5 W
Standby (information or status display plus reactivation function	1.0 W

3.8 VOLUNTARY PROGRAMS

DOE reviewed voluntary programs promoting energy efficient residential cooking products in the United States. DOE noted that FEMP establishes voluntary energy conservation standards for microwave ovens.

DOE's FEMP[f] works to reduce the cost and environmental impact of the Federal government by advancing energy efficiency and water conservation, promoting the use of distributed and renewable energy, and improving utility management decisions at Federal sites.

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[e] Japan's Energy Conservation Act uses a "top runner" method to set energy efficiency targets for residential, commercial, and transportation sector equipment. Target values for future products are set based on the level of the most energy efficient products on the market at the time of the value setting process. For more information, visit *http://www.eccj.or.jp/index_e.html*

[f] For more information visit *http://www.eere.energy.gov/femp*.

FEMP helps Federal buyers identify and purchase energy efficient equipment, including microwave ovens.

Executive Order 13221 Energy Efficient Standby Power Devices, signed July 31, 2001, requires that Federal agencies purchase commercially available products with low standby power. 66 FR 40571. FEMP, therefore, issues standby power recommendations for microwave ovens. Table 3.8.3 presents the microwave oven recommendations.

Table 3.8.1 FEMP Recommendations for Microwave Ovens

Microwave Oven Classification	Standby Power (*W*)*
Standard Microwave Oven	≤ 2

* Based on test procedures specified in IEC Standard 62301

3.9 HISTORICAL SHIPMENTS

Awareness of annual product shipment trends is an important aspect of the market assessment and in the development of the standards rulemaking. DOE reviewed data collected by the U.S. Census Bureau and AHAM to evaluate residential appliance product shipment trends and the value of these shipments, which were used during the shipments analysis (chapter 9 of this TSD.)

3.9.1 New Home Starts

Trends in new home starts may directly affect shipments of certain home appliances. While there is certainly both a replacement and remodeling market for some appliances including microwave ovens, these products are also fixtures in virtually all new homes.

Figure 3.6.1 presents the number of new single-family and multi-family housing units started in the United States from 1998–2009. Over the 5-year period from 2000–2005, single-family home starts increased 39.4 percent, to 1,716,000 units annually. However, between 2005 and 2009, single-family home starts decreased 74.1 percent, to 445,100 units annually. Multi-family unit starts have remained relatively flat between 1998 and 2005, hovering around 350,000 units annually. However, between 2005 and 2009, multi-family unit starts decreased by 69.1 percent, to around 108,900 units annually.[15]

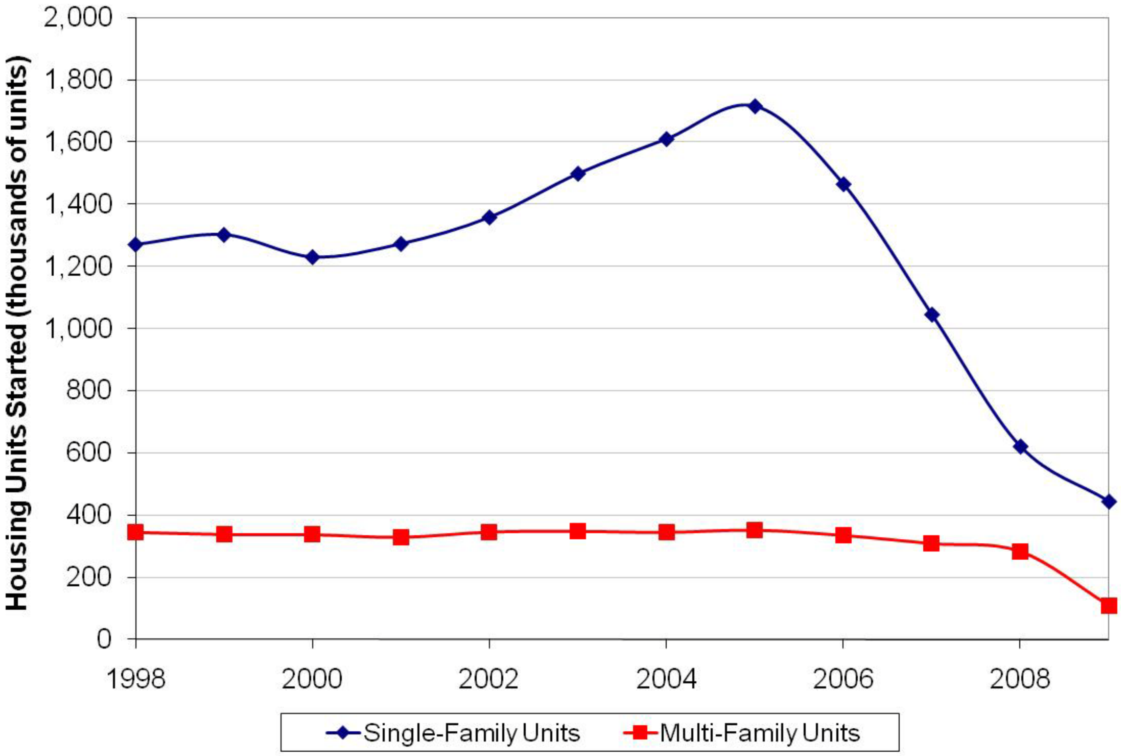

Figure 3.9.1 New Privately Owned Single-Family and Multi-Family Housing Unit Starts in the United States from 1998–2009 [16]

3.9.2 Unit Shipments

Appliance Magazine provides annual unit shipments for residential appliances, including microwave ovens. Table 3.9.1 presents annual shipments of microwave ovens. The shipments of microwave ovens increased 90.2 percent from 1995 to 2004, to about 15.5 million units in 2004. However, between 2004 and 2008, shipments of microwave ovens decreased by 27 percent, to 11.3 million units in 2008.

Table 3.9.1 Industry Shipments of Microwave Ovens (Domestic and Import in Thousands of Units) [17]

Year	Microwave Ovens
2008	11,340
2007	not available
2006	13,889
2005	13,862
2004	15,526
2003	14,274
2002	13,311
2001	13,446
2000	12,644
1999	11,422
1998	10,365
1997	8,883
1996	8,771
1995	8,162

3.9.3 Value of Shipments

Table 3.9.2 provides the value of shipments for the household appliance industry from 1994–2009 based upon data from the U.S. Census Bureau's *Annual Survey of Manufacturers* (ASM).[g] The ASM expresses all dollar values in nominal dollars; *i.e.*, 2009 data are expressed in 2009 dollars, and 2008 data are expressed in 2008 dollars. Using the Gross Domestic Product Implicit Price Deflator, DOE converted each year's value of shipments to 2009 dollars. In constant 2009 dollars, the value of shipments has declined by approximately 40 percent over the 16-year period.

[g] Available online at http://www.census.gov/mcd/asm-as1.html.

Table 3.9.2 Household Appliance Manufacturing Statistics by Year[18]

Year	Value of Shipments in Nominal Dollars (*$1000*)	Value of Shipments in 2009 Dollars (*$1000*)
2009	18,707,942	18,707,942
2008	21,504,780	21,701,972
2007	23,639,716	24,377,846
2006	24,162,513	25,650,308
2005	24,620,117	26,987,341
2004	23,989,141	27,173,398
2003	23,026,196	26,822,704
2002	22,269,541	26,499,444
2001	22,298,897	26,964,077
2000	23,414,965	28,953,393
1999	22,372,219	28,263,078
1998	22,471,878	28,806,293
1997	21,394,445	27,735,227
1996	22,156,900	29,230,799
1995	22,391,300	30,102,315
1994	22,793,900	31,281,968

The increase in shipment volumes combined with an overall decrease in constant-dollar shipment values indicates that the U.S. appliance industry is very competitive.

According to data presented in the AHAM *Fact Book 2003*, many old appliances are still being used after consumers purchase new units of same product. Table 3.9.3 presents the various methods by which consumers dispose of their older appliances.

Table 3.9.3 Disposition of Previous Appliance (*Percentage*)[19]

Product	Kept It	Left with Previous Home	Sold / Gave Away	Recycling Facility	Left at Curb for Disposal	Retailer Took Away
Microwave Ovens	17	11	32	12	23	4

The value of shipments of residential cooking products, a subset of the household appliance industry as defined in the ASM, has fluctuated over the last 16 years when viewed in 2009 real dollars. Overall, the real value of shipments in 2009 was roughly 27 percent lower than the value in 1994. Table 3.9.4 provides the industry value of shipments for household cooking appliance manufacturing.

Table 3.9.4 Household Cooking Appliance Manufacturing Statistics by Year[20]

Year	Value of Shipments in Nominal Dollars (*$1000*)	Value of Shipments in 2009 Dollars (*$1000*)
2009	3,835,185	3,835,185
2008	4,261,482	4,300,558
2007	4,786,768	4,936,231
2006	4,864,268	5,163,783
2005	5,114,677	5,606,453
2004	4,798,227	5,435,131
2003	4,691,713	5,465,272
2002	4,327,308	5,149,242
2001	3,773,442	4,562,889
2000	4,178,958	5,167,422
1999	3,915,499	4,946,494
1998	3,849,167	4,934,177
1997	3,520,635	4,564,064
1996	3,564,700	4,702,780
1995	3,788,200	5,092,763
1994	3,813,900	5,234,133

3.9.4 Imports and Exports

There is a large market for the import and export of home appliances. Each month AHAM publishes import and export data for certain home appliances. These data are released by the U.S. Census Bureau and aggregated by a third party. On the whole, major appliance unit imports decreased 9.7 percent in 2009 as compared to 2008. Major appliance unit exports decreased 17.5 percent over the same period.

Table 3.9.5 shows selected import data from AHAM's *Import/Export Trade Report – December 2009.*[21] For microwave ovens less than or equal to 22.5 inches in width, both the number and value of units imported decreased by more than 17 percent from 2008 to 2009.. For microwave ovens 22.5 inches to 31.0 inches in width, both the number and value of units imported increased by more than 14 percent from 2008 to 2009. For microwave ovens greater than 31.0 inches in width, both the number and value of units imported decreased by more than 10 percent. Overall, the value of major appliance imports decreased 9.2 percent from 2008 to 2009.

Table 3.9.5 2008–2009 Imports of Microwave Ovens[22]

Appliance Description	Jan. – Dec. 2009	Jan. – Dec. 2008	% Change	Jan. – Dec. 2009	Jan. – Dec. 2008	% Change
	Units			*$ Mil (Nominal)*		
Microwave ovens ≤ 22.5 inches	3,776,772	4,567,709	-17.3	130.042	165.033	-21.2
Microwave ovens > 22.5-31.0 inches	3,263,577	2,392,880	36.4	135.885	118.232	14.9
Microwave ovens > 31.0 inches	7,442,569	8,378,,434	-11.2	610.732	679.688	-10.1

Table 3.9.6 shows selected export data from AHAM's *2007 Import/Export Trade Report – December 2009*.[23] For the 1-year period from 2008 to 2009, both the number and value of unit exports of microwave oven exports decreased by more than 16 percent. Overall, the total value of exports decreased 18.9 percent.

Table 3.9.6 2008–2009 Exports of Microwave Ovens [24]

Appliance Description	Jan. – Dec. 2009	Jan. – Dec. 2008	% Change	Jan. – Dec. 2009	Jan. – Dec. 2008	% Change
	Units			*$ Mil (Nominal)*		
Microwave ovens	235,883	294,660	-19.9	33.479	40.083	-16.5

3.10 MARKET SATURATION

AHAM's *Fact Book 2005* presents the market saturation for microwave ovens. As shown in Table 3.10.1, the percentage of households with microwave ovens has decreased slightly since 2001. The number of U.S. households with microwave ovens is based on U.S. Census Bureau projections of occupied units in the relevant year.

Table 3.10.1 Appliance Saturation (Number in Millions) and Percentage of U.S. Households with Product [25]

Product	1970		1982		1990		2001		2005	
	#	%	#	%	#	%	#	%	#	%
Microwave Ovens	Neg.	Neg.	21.4	25.6	77.2	82.7	94.6	90.7*	97.2	89.3

* Includes over-the-range and countertop microwave ovens

3.11 PRODUCT RETAIL PRICES

Table 3.11.1 presents the average retail prices (in nominal dollars) of microwave ovens and the Consumer Price Index (CPI) of each year (1982–84 = 100). Prices of microwave ovens have decreased since 1980.

Table 3.11.1 Residential Appliance Retail Prices [26]

Product	Average Retail Prices (*Nominal $*)				Percent Change
	1980	1994	2002	2005	1980–2005
Microwave Ovens	450	239	145	99	-78.0%
Consumer Price Index[*]	*82.4*	*148.2*	*179.9*	*195.3*	*137.0%*

[*] U.S. Department of Labor, Bureau of Labor Statistics, Consumer Price Index: U.S. city average. 1982–84 = 100.

3.12 INDUSTRY COST STRUCTURE

DOE developed the household appliance industry cost structure from publicly available information from the ASM, (Table 3.12.1 and Table 3.12.2) and the U.S. Securities and Exchange Commission (SEC) 10-K reports filed by publicly owned manufacturers (summarized in Table 3.12.3). Table 3.12.1 presents the home appliance industry employment levels and earnings from 1994-2009. The statistics illustrate a steady decline in the number of production and non-production workers in the industry.

Because the ASM expresses all dollar values in constant 2009 dollars, the following table shows that as industry employment levels decline, the industry payroll is also decreasing. The percent decrease in total industry employees tracks closely with the percent decrease in payroll for all employees.

Table 3.12.1 Household Appliance Industry Employment and Earnings [27]

Year	**Production Workers (*'000*)**	**All Employees (*'000*)**	**Payroll for All Employees (*2009 $ Mil*)**
2009	41.1	48.6	1,938.7
2008	48.0	56.4	2,269.4
2007	56.2	65.5	2,562.4
2006	60.0	69.7	2,806.8
2005	64.3	76.9	2,958.7
2004	69.4	83.7	3,278.0
2003	71.0	85.3	3,360.8
2002	73.5	88.8	3,562.0
2001	76.6	92.6	3,732.0
2000	82.7	99.5	4,065.4
1999	82.3	97.9	3,932.8
1998	82.4	99.5	3,960.4
1997	79.8	97.2	3,781.3
1996	87.1	108.1	4,052.5
1995	88.9	110.8	4,119.6
1994	90.4	110.4	4,105.5

Table 3.12.2 presents the employments levels and earnings for just the household laundry portion of the appliance industry from 1994-2009. Statistics for both employment levels and payroll show a steady fluctuation from 1994-2002, but both have declined since that time. Payroll and employment levels again show a positive correlation.

Table 3.12.2 Household Cooking Appliance Industry Employment and Earnings [28]

Year	Production Workers (*'000*)	All Employees (*'000*)	Payroll for All Employees (*2009 $ Mil*)
2009	8.7	10.0	353.0
2008	10.4	11.8	411.2
2007	13.1	15.5	480.4
2006	12.7	14.4	466.7
2005	14.3	16.4	567.8
2004	14.4	17.0	584.1
2003	14.5	17.3	572.3
2002	14.7	18.0	592.6
2001	14.8	17.5	596.9
2000	15.3	18.0	633.3
1999	16.4	19.1	701.5
1998	15.3	18.2	670.5
1997	14.4	17.5	619.1
1996	14.7	18.1	682.6
1995	15.2	19.2	678.0
1994	15.0	18.6	674.1

Table 3.12.3 presents the costs of materials and industry payroll as a percentage of value of shipments from 1994–2009. The cost of materials as a percentage of value of shipments has fluctuated slightly over the 15-year period. DOE notes that fluctuations in raw material costs are common from year to year. The cost of payroll for production workers as a percentage of value of shipments has declined since 2000. Similarly, the cost of total payroll as a percentage of value of shipments has declined since 2000.

Table 3.12.3 Household Appliance Industry Census Data [29]

Year	Cost of Materials as a Percentage of Value of Shipments (%)	Cost of Payroll for Production Workers as a Percentage of Value of Shipments (%)	Cost of Total Payroll (Production + Admin.) as a Percentage of Value of Shipments (%)
2009	54.0	7.5	10.4
2008	59.3	7.7	10.5
2007	57.8	8.0	10.5
2006	57.9	8.4	10.9
2005	56.9	8.3	11.0
2004	57.2	9.0	12.1
2003	55.9	9.2	12.5
2002	54.9	9.7	13.4
2001	56.8	10.1	13.8
2000	55.8	10.2	14.0
1999	54.7	10.2	13.9
1998	56.0	10.0	13.7
1997	52.8	9.9	13.6
1996	56.8	9.9	13.9
1995	57.7	9.4	13.7
1994	55.5	9.2	13.1

Table 3.12.4 shows the cost of materials and industry payroll as a percentage of value of shipments for the household cooking appliance industry from 1994-2009. DOE observed a decline in the cost of payroll as a percentage of value of shipments from 1999–2009. During that same time period, the cost of materials as a percentage of value of shipments has increased.

Table 3.12.4 Household Cooking Appliance Industry Census Data [30]

Year	Cost of Materials as a Percentage of Value of Shipments (%)	Cost of Payroll for Production Workers as a Percentage of Value of Shipments (%)	Cost of Total Payroll (Production + Admin.) as a Percentage of Value of Shipments (%)
2009	60.7	6.8	9.2
2008	70.5	7.4	9.6
2007	64.3	7.4	9.7
2006	66.8	7.0	9.0
2005	67.9	8.0	10.1
2004	67.3	8.1	10.7
2003	63.2	7.5	10.5
2002	64.6	8.0	11.5
2001	63.3	9.3	13.1
2000	57.1	8.5	12.3
1999	58.4	10.1	14.2
1998	57.8	9.3	13.6
1997	51.0	9.4	13.6
1996	61.5	9.3	14.5
1995	53.6	8.4	13.3
1994	52.2	8.5	12.9

A detailed financial analysis of each of the products covered by this rulemaking is presented in the manufacturer impact analysis. (See chapter 12 of this TSD.) This analysis identifies key financial inputs including cost of capital, working capital, depreciation, and capital expenditures.

3.13 INVENTORY LEVELS AND CAPACITY UTILIZATION RATES

Table 3.13.1 and Table 3.13.2 show the year-end inventory for the household appliance and household cooking appliance industries, respectively, according to the ASM. Both in dollars and as a percentage of value of shipments, the end-of-year inventory for the industry has declined since 1995. These data illustrate a general trend of domestic manufacturers retaining less of their inventories over time since 1994.

Table 3.13.1 Household Appliance Industry Census Data [31]

Year	End-of-Year Inventory (*2009 $ Mil*)	End-of-Year Inventory as a Percentage of Value of Shipments (*%*)
2009	1,587.6	8.5
2008	1,868.1	8.6
2007	2,059.7	8.4
2006	1,792.5	7.0
2005	1,790.5	6.6
2004	1,979.7	7.3
2003	1,984.5	7.4
2002	2,133.8	8.1
2001	2,372.1	8.8
2000	2,676.6	9.2
1999	2,667.2	9.4
1998	2,875.6	10.0
1997	2,763.9	10.0
1996	3,033.1	10.4
1995	3,350.0	11.1
1994	3,472.3	11.1

Table 3.13.2 Household Cooking Appliance Industry Census Data [32]

Year	End-of-Year Inventory (*2009 $ Mil*)	End-of-Year Inventory as a Percentage of Value of Shipments (*%*)
2009	296.1	7.7
2008	391.7	9.1
2007	574.6	11.6
2006	409.2	7.9
2005	474.0	8.5
2004	464.8	8.6
2003	454.6	8.3
2002	513.4	10.0
2001	404.2	8.9
2000	456.4	8.8
1999	513.1	10.4
1998	610.6	12.4
1997	528.1	11.6
1996	606.3	12.9
1995	720.5	14.1
1994	734.9	14.0

DOE obtained full production capacity utilization rates from the U.S. Census Bureau, *Survey of Plant Capacity* from 1994–2006. Table 3.13.2 presents utilization rates for various sectors of the household appliance industry. Full production capacity is defined as the maximum level of production an establishment could attain under normal operating conditions. In the *Survey of Plant Capacity* report, the full production utilization rate is a ratio of the actual level of operations to the full production level. The full production capacity utilization rate for household appliances in aggregate, along with the rates for cooking appliances and household laundry appliances, show a decrease in utilization from 1994–2006, although trends in subsets of that time period have fluctuated.

Table 3.13.3 Full Production Capacity Utilization Rates[33]

Year	Rates (%)	
	Household Appliances	Cooking Appliances
2006	77	65
2005	74	57
2004	76	61
2003	78	57
2002	72	56
2001	70	50
2000	70	55
1999	75	59
1998	73	66
1997	73	61
1996	76	66
1995	79	66
1994	82	72

3.14 TECHNOLOGY ASSESSMENT

This section provides a technology assessment for residential microwave ovens. Contained in this technology assessment are details about product characteristics and operation (section 3.14.1), an examination of possible technological improvements (section 3.14.2), and a characterization of the product efficiency levels currently commercially available (section 3.14.3).

3.14.1 Product Operations and Components

In preparation for the screening and engineering analyses, DOE prepared a brief description of the characteristics and operation of microwave ovens. This description provides a basis for understanding the technologies used to improve product efficiency.

A microwave oven is an appliance which heats foods and beverages through the conversion of electric energy to electromagnetic (microwave) energy. The food load is placed inside the oven where it is subjected to the microwave energy. In the portion of the electromagnetic spectrum where microwave ovens operate, typically 2.45 gigahertz, water, fats, and sugars have high absorptivity and thus food heats readily. Glass, ceramic, and paper have low absorptivity at these wavelengths, while metals reflect the microwaves. Therefore microwave ovens efficiently heat foods while the cavity and utensils remain cool.

The microwave energy is generated by an electrically powered magnetron. Line voltage is converted to the high voltage required by the magnetron through the use of a high-voltage transformer. The microwaves are directed from the magnetron into the cavity via a metal duct, or waveguide. To produce a more uniform distribution of energy in the cavity, one or more sets of rotating metal blades may be inserted in the waveguide to alter the microwave patterns temporally. Additionally, a turntable or translating tray may be provided in the cavity to move the load and thus promote even input energy distribution to the food. Some microwave ovens are equipped with electrically powered resistive or halogen heating elements for surface browning, and in the case of combination microwave ovens, an additional fan for forced air distribution to enhance cooking performance.

To achieve reduced power levels for cooking processes such as defrosting, the magnetron is typically cycled at an appropriate duty cycle which results in a time-averaged power at the desired level. Electronic controls may include a clock/timer function as well as a humidity or infrared sensor for detecting when the desired level of cooking is achieved. Standby power consumption associated with these electronics, as well as the power supply, may be several watts. In addition, a light is typically provided that is turned on when the door is opened or when the microwave oven is in operation.

Installation configurations include countertop and over-the-range. Over-the-range microwave ovens may include a ventilation fan that turns on automatically when the temperature from the cooktop below it rises; however, such an option is not required for certification under the Underwriters Laboratories (UL) Standard UL 923 - Edition 5, *Standard for Microwave Cooking Appliances*.

3.14.2 Technology Options

In order to gain a deeper understanding of the technological improvements used to increase the efficiency of microwave ovens, DOE identified several possible technologies and examined the most common improvements used in today's market. Because DOE only intends to address energy conservation standards for standby mode and off mode in this rulemaking, the following discusses only technology options associated with reducing standby mode and off mode energy consumption.

For microwave oven standby power, DOE investigated technology options for decreasing standby power. DOE identified lower-power display technologies, cooking sensors with no standby power requirement, improved power supplies, improved control boards, and automatic power-down from research, literature review, and reverse-engineering conducted as part of the microwave oven analysis discussed in chapter 5 of this TSD.

Table 3.14.1 Technology Options for Microwave Oven – Standby Power

1.	Lower-power display technologies
2.	Cooking sensors with no standby power requirement
3.	Improved power supply and control board options
4.	Automatic power-down

Lower-power display technologies

Microwave ovens are generally constructed using one of the following display types to show clock time and other parameters: (1) vacuum fluorescent display (VFD); (2) backlit and non-backlit liquid crystal display (LCD); and (3) light-emitting diode (LED) display. Within the 32-unit sample that DOE examined as part of the supplemental microwave oven analysis, microwave ovens equipped with VFDs consumed the most power on average, followed by units featuring backlit LCDs, LED displays and non-backlit LCDs. Data gathered by DOE show that standby power levels between 1.1 W and 1.4 W have been achieved in microwave ovens using either LED displays or LCDs, and standby power as low as 1.7 W has been achieved using a backlit LCD. The lowest standby power observed for a microwave oven with a VFD was 2.5 W. One display manufacturer stated to DOE that backlit LCDs can consume up to 50 percent less energy than VFDs in sizes applicable to microwave ovens, depending on the number of LED backlights used to light the display. The manufacturer also stated that power requirements for LED displays are generally lower than for VFDs, but the difference depends considerably on the number of diode segments being lit.

The display format on each microwave oven can be characterized as either numeric, alphanumeric, or dot matrix. Whereas numeric displays can only show time, alphanumeric displays can also display letters, though usually in simplified format. Dot matrix displays can show various fonts, letters, and symbols via matrices of pixels, making them the most flexible display technology. In the reverse-engineering analysis DOE conducted as part of chapter 5 of this TSD, DOE observed that LED displays found in microwave ovens generally contain four numeric characters and a row of small words. LCDs and VFDs allow for more flexibility in the numbers and words being displayed by using alphanumeric characters without increasing the power requirements. LED displays could conceivably achieve this, but would require more diode segments, increasing the cost of the display. However, this would not affect standby power, assuming that in standby mode only the clock time is being displayed.

Cooking sensors with no standby power requirement

Cooking sensors detect that a desired cooking state of the food load has been reached and then signal the controller to shut off the microwave oven, thereby preventing excess energy consumption in addition to optimizing food quality. During product teardowns (see chapter 5 of this TSD), DOE found that the most common identifiable cooking sensors are absolute humidity sensors, which infer the cooking state of the food load from the amount of water vapor being released into the cavity. This sensor technology requires standby power in the range of 1–2 W to maintain a resistive heating element, whose conductivity changes in response to the presence of water vapor or other gases, at operating temperature. If the power to the sensor is switched off and back on, warm-up times in excess of two minutes may be required. Standby testing by DOE and AHAM revealed no microwave ovens with cooking sensors that consume less than 2 W in standby mode. One Japanese microwave oven manufacturer stated during discussions with DOE that they are unaware of any humidity sensors that do not require standby power to stay warm.

DOE has conducted research of cooking sensor technologies and has identified cooking sensors with zero standby power requirements and little to no warm-up time. During the reverse-engineering analysis for microwave ovens (discussed in more detail in chapter 5 of this TSD), DOE observed that microwave ovens from one manufacturer use a piezoelectric steam sensor which requires zero power in standby mode. This sensor technology functions by detecting a burst of steam created from moisture in the food as it cooks. Low frequency (approximately 10 hertz) components of the output signal of the device correlate with the amount of hot steam emitted from the load. In addition to steam sensors, DOE has identified infrared and weight sensors with little to no warm-up time that do not consume standby power and that have been applied in microwave ovens currently on the Japanese market. Infrared cooking sensors detect the temperature of the load in the field of view of the sensing element. These sensors may require multiple elements or a motor to rotate the sensor in order to expand the field of view to accurately measure the temperature of the food load depending on where it is placed in the oven cavity. Weight sensors determine the cooking state based upon the reduction in weight of the food load, which results from moisture evaporating from the load. DOE has also identified relative humidity sensors as a type of zero-standby power sensor that can be applied in a microwave oven, but is unaware of any microwave ovens on the market that use this type of sensor. Lastly, DOE was made aware of an absolute humidity sensor that requires no standby power, has zero incremental cost above that of a conventional absolute humidity sensor, and is in the process of being phased into production for a major microwave oven supplier to the US market.

Improved power supply and control board options

A potential area for standby power improvements is the power supplies on the control board. Multiple improvement paths with varying risk to manufacturers are available, including the selective upgrading of power supply components to boost efficiency, the reduction of peak power demand through the use of lower-power components, and the transition to switching power supplies.

Typically, microwave ovens incorporate unregulated plus regulated control board power supplies (also referred to as a linear power supply). The unregulated portion consists of a small transformer, a bridge rectifier, and an electrolytic capacitor. Voltage regulators then step down the voltage(s) to the level(s) required by the control logic, display, and cooking sensor. This approach results in a rugged power supply which is reliable, but typically has an efficiency of about 55 percent.

According to power supply topology experts that DOE consulted, the quality of the transformer core material, diode type, capacitor quality, and voltage regulator selection could cut no-load standby power for the power supply in half and boost conversion efficiency from 55 to 70 percent. For a typical 5 W-output microwave-only unit power supply, that no-load power consumption improvement is approximately 0.4 W.

DOE also notes that switching from electromechanical relays (used to drive components such as heaters, motors, lights, etc.) to solid state relays capable of driving the same loads as the electromechanical relays would decrease the total power requirements of the control board and thus decrease the standby losses of the power supply. As a result the overall standby power consumption of the microwave oven would also decrease.

Switching power supplies offer the highest conversion efficiencies of up to 75 percent for switch mode power supply designs for appliance applications for power supply sizes similar to those of microwave ovens[h] and lowest no-load standby losses (0.2 W or less), though at a higher cost, higher part count, and greater complexity. DOE is unaware of any switching power supply designs for application in microwave ovens that can achieve efficiencies above 75 percent. Switching power supplies greater complexity may also result in lower overall reliability and take greater care to implement. For example, among other issues, a switching power supply can be prone to causing electromagnetic interference. DOE notes that there already are some premium microwave ovens on the U.S. market that incorporate switching power supplies. However, due to the incremental cost of such a power supply over a conventional linear power supply and the price competition in the microwave oven market, it is unlikely that switching power supplies will find wider application unless low standby power budgets force manufacturers to consider them.

Automatic power-down

Manufacturers could also meet very low (*i.e.*, less than 1 W) standby power levels according to the definition of "standby mode" in the DOE test procedure by incorporating an automatic function that turns off most power-consuming components once a period of inactivity has elapsed. Such a low-consumption state could be user-selectable on demand, or could be the default condition in which the microwave oven is shipped such that the consumer would be required to opt in to maintaining the display, cooking sensor, or other utility feature during standby. DOE has determined that some microwave oven suppliers to the U.S. market have already taken such approaches to meet prescriptive standby power standards in other markets such as Japan. DOE understands that such a technology option may be implemented using a transformerless power supply for the microprocessor logic, along with a linear conventional power supply that is activated when the unit goes into active mode. Such a power supply design, incorporated with a "soft" power pushbutton or door limit switch and Triac to control power through the transformer, would provide just enough power through the transformerless power supply to maintain the microcontroller chip while the microwave oven is not powered on. When

[h] Information on design and efficiencies of switch mode power supplies is available from Power Integrations: http://www.powerint.com/en/applications/major-appliances.

the power button is pressed or the oven door is opened, current would then be allowed to pass through the transformer of the conventional linear power supply to power the remainder of the control board.

3.14.3 Energy Efficiency

In preparation for the screening and engineering analyses, DOE gathered data on the energy efficiency of microwave ovens currently available in the marketplace. These data were taken from databases maintained by a variety of regulatory agencies. While this section is not intended to provide a complete characterization of the energy efficiency of all appliances currently available and in use, it does provide an overview of the energy efficiency of microwave ovens covered by this rulemaking.

Microwave ovens consume energy in standby mode while powering the clock and electronic controls. AHAM recently provided data on microwave oven standby power for a sample of microwave ovens available in the U.S. market.[34] Figure 3.14.1 displays AHAM-measured microwave oven standby power data as a function of rated cooking output power. Figure 3.14.1 also contains standby power measurements made by the Canadian Building Energy End-Use Data and Analysis Center (CBEEDAC) at the University of Alberta. The data show a wide range of standby power, but there is no correlation between standby power and rated cooking output power. The data did not indicate the product type (*i.e.*, microwave only, combination) or the installation configuration (*i.e.*, countertop, over-the-range, built-in).

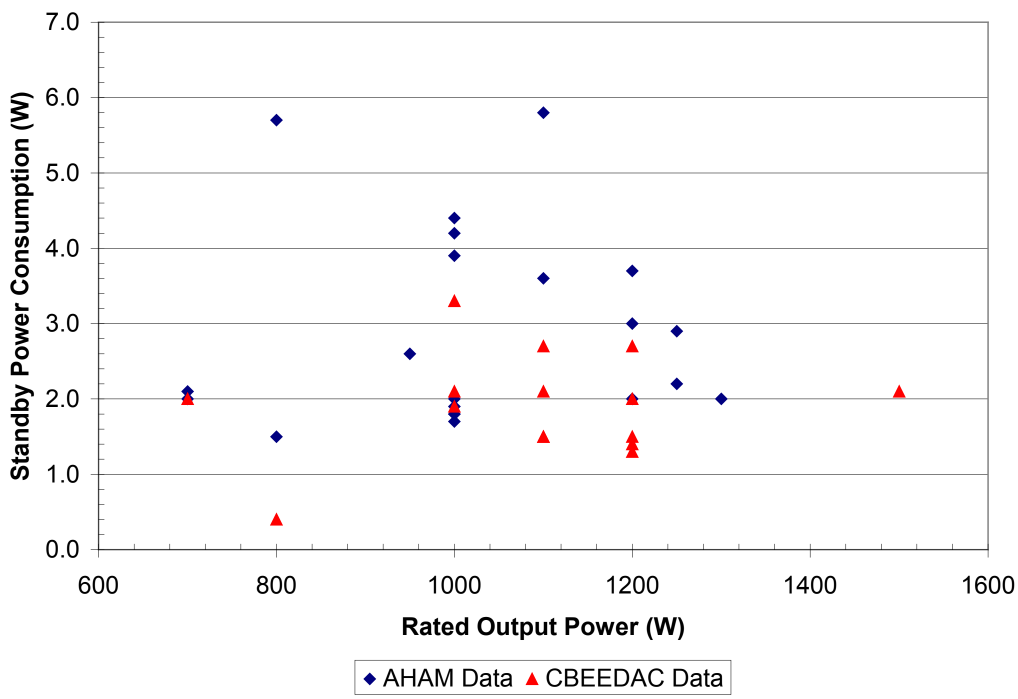

Figure 3.14.1 AHAM and CBEEDAC Microwave Oven Standby Power versus Rated Output Power[35,36]

FEMP publishes a database of microwave ovens, sorted by standby power, although this database is also not completely representative of microwave ovens available in the U.S. market. Figure 3.14.2 displays the number of microwave oven models available with different standby power levels as listed in the FEMP standby power database.

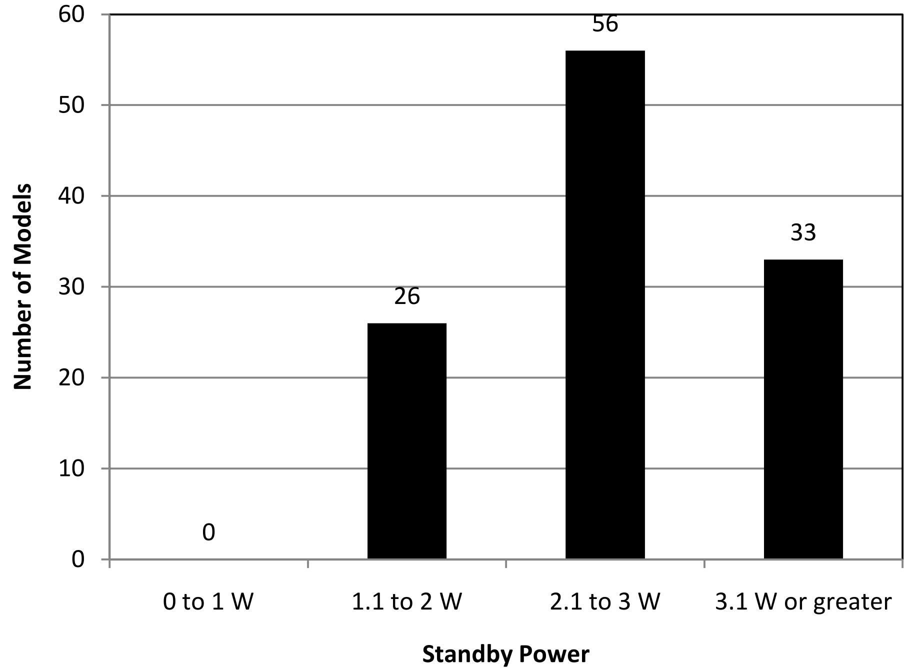

Figure 3.14.2 Microwave Oven Standby Power Consumption from the FEMP Database[37]

FEMP does not specify microwave oven rated cooking output power. Therefore, it is not possible to make a direct comparison between the FEMP microwave oven standby power data and the AHAM microwave oven test data. However, the distributions of standby power in the FEMP database and the AHAM data are similar. No residential microwave ovens consume less than 1 W of standby power, some microwave ovens consume less than 2 W of standby power, but the large majority of microwave ovens consume between 2.1 and 3 W of standby power.

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