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 cooking product and commercial clothes washer industries 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 "**cooking products**" under the Energy Policy and Conservation Act (EPCA) of 1975 (42 U.S.C. 6291–6309) as "consumer products that are used as the major household cooking appliances. They are designed to cook or heat different types of food by one or more of the following sources of heat: gas, electricity, or microwave energy. Each product may consist of a horizontal cooking top containing one or more surface units and/or one or more heating compartments. They must be one of the following classes: conventional ranges, conventional cooking tops, conventional ovens, microwave ovens, microwave/conventional ranges and other cooking products." (10 CFR 430.2)

The Energy Policy Act of 2005 (EPACT 2005) (Pub. L. 109-58) established the definition of a **commercial clothes washer** (CCW) as follows:

The term 'commercial clothes washer' means a soft-mount, front-loading or soft-mount, top-loading clothes washer that:

A) has a clothes compartment that:
    i) for horizontal-axis clothes washers, is not more than 3.5 cubic feet; and
    ii) for vertical-axis clothes washers, is not more than 4.0 cubic feet; and
B) is defined for use in:
    i) applications in which the occupants of more than 1 household will be using the clothes washer, such as multi-family housing common areas and coin laundries; or
    ii) other commercial applications.

(EPACT 2005, section 136(a)(4))

3.3 PRODUCT CLASSES

DOE intends to separate each product (residential cooking products and CCWs) 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) and 6316(a))

For **cooking products**, the proposed product classes are based on energy source (*i.e.*, gas or electric) and the cooking method (*i.e.,* cooktops, ovens, and microwave ovens). There are five cooking product classes: (1) gas cooktops; (2) electric cooktops; (3) gas ovens; (4) electric ovens; and (5) microwave ovens. DOE's proposed product classes are based on the list of classes defined by DOE in its 1996 *Technical Support Document for Residential Cooking Products* (1996 TSD), which was released as part of the previous standards rulemaking.[a] Gas and electric ranges[b] are not listed below as product classes. Because ranges consist of both a cooktop and oven, any potential cooktop and oven standards would apply to the individual components of the range. As a result, product classes for ranges are not necessary.

For **gas cooktops**, DOE's proposed product class is:

- Conventional burners.

Commercial-style gas burners, which are characterized by firing rates greater than 14,000 British thermal units per hour (Btu/h) will not be considered for analysis due to a lack of available data for determining efficiency characteristics. In addition, the test procedure for gas cooktops is based on measuring temperature rise in an aluminum block with a diameter dictated by the firing rate of the burner. The maximum diameter of the test block is sufficient to measure higher output residential-scale burners. For commercial-type burners that must have larger diameter burner rings to accomplish complete combustion, however, this maximum test block diameter may be too small to achieve proper heat transfer and may not be representative of the dimensions of suitable cookware.

For **electric cooktops**, DOE's 1996 TSD determined that the ease of cleaning smooth elements provides enhanced consumer utility over coil elements. Because smooth elements typically use more energy than coil elements, DOE is proposing the following product classes for electric cooktops:

- Low or high wattage open (coil) elements; and
- Smooth elements.

Gas and electric grills and griddles will not be analyzed because DOE is not aware of any data upon which it can base a determination of either adequacy of the test procedure to measure energy efficiency or energy efficiency characteristics of products in these niche classes.

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[a] Available online at *http://www.eere.energy.gov/buildings/appliance_standards/residential/cooking_products.html*

[b] DOE defines a "conventional range" under EPCA as "a class of kitchen ranges and ovens which is a household cooking appliance consisting of a conventional cooking top and one or more conventional ovens." (10 CFR 430.2)

For **electric ovens**, the 1996 TSD determined that the type of oven-cleaning system is a utility feature that affects performance. DOE found that standard ovens and ovens using a catalytic continuous-cleaning process use roughly the same amount of energy. On the other hand, self-cleaning ovens use a pyrolytic process that provides enhanced consumer utility with lower overall energy consumption as compared to either standard or catalytically lined ovens. Thus, DOE is proposing the following product classes for electric ovens:

- Standard oven with or without a catalytic line; and
- Self-clean oven.

For **gas ovens**, for the same reasons as for electric ovens, DOE is proposing the following product classes:

- Standard oven with or without a catalytic line; and
- Self-clean oven.

DOE proposed in the advance notice of proposed rulemaking (ANOPR), published on November 15, 2007 (November 2007 ANOPR), that standing pilot ignition systems do not provide unique utility that would warrant a separate product class for gas cooking products incorporating them. 72 FR 64463. In considering standing pilot ignition systems as either a separate product class or a design option, DOE notes that the purpose of such systems is to ignite the gas when burner operation is called for during a cooking process, and either standing pilot or electronic ignition provides this function. In addition, DOE has concluded from previous analysis that the average consumer does not experience frequent enough or long enough power outages to consider the ability to operate in the event of an electric power outage a significant utility.

DOE also addressed a similar issue in the residential furnace and boiler rulemaking, where DOE made an exception to allow standing pilot ignition for gravity gas-fed boilers. Gravity gas-fed boilers, however, are a type of heating equipment that represent a unique utility in that they do not require an electric circulation motor to operate, a utility which happens to accommodate religious and cultural practices which prohibit electronic ignition as well. Thus, the exception is based on continuing to allow products with certain performance characteristics to be available to all consumers. But DOE is unable to create a similar exception for gas cooking products because there is no unique utility associated with standing pilot ignition.

Through market research, DOE determined that battery-powered electronic ignition systems have been implemented in other products, such as instantaneous gas water heaters, barbeques, furnaces, and other appliances, and the use of such ignition systems appears acceptable under the applicable safety standards contained in the American National Standards Institute (ANSI) Z21.1-2005 and Addenda 1-2007, *Household Cooking Gas Appliances* (ANSI Z21.1). Therefore, subgroups with religious and cultural practices which prohibit the use of line electricity (*i.e.*, electricity from the utility grid) can still use gas cooking products without standing pilots, assuming gas cooking products are made available with battery-powered ignition. Furthermore, there is not expected to be any appreciable difference in cooking performance between gas cooking products with or without a standing pilot. Thus, DOE concludes that standing pilot ignition systems do not provide a distinct utility and that a separate class for standing pilot ignition systems is not warranted under section 325(q)(1) of EPCA. (42 U.S.C. 6295(q)(1))

Commercial-style gas ovens, with larger cavity volumes (*i.e.*, those that correspond to cabinet widths of 36 inches) and higher firing rate burners (*i.e*., greater than 22,500 Btu/h), will not be analyzed as a separate product class. DOE recognizes that the test procedure may not adequately measure performance of commercial-style ovens because the single test block may not adequately measure the temperature distribution that is inherent with these products. Further, DOE is unaware of efficiency data or data evaluating the adequacy of the test procedure, so therefore will not conduct an analysis on this product class at this time.

For **microwave ovens**, DOE proposes no further class breakdown. This product class can encompass microwave ovens with and without browning elements, but does not include microwave ovens that incorporate convection systems (combination ovens). DOE will not conduct an analysis at this time of combination microwave ovens due to a lack of data evaluating the applicability of the test procedure to microwave ovens incoporating convection systems.

For **commercial clothes washers**, DOE is proposing the following product classes based on the method of access:

- Top-loading washers
- Front-loading washers

Typically, top-loading clothes washers (also known as top-loaders) have a wash basket that rotates around a vertical axis, while front-loader clothes washers (also known as front-loaders) have a wash basket that rotates around a horizontal axis. However, a limited number of residential horizontal-axis clothes washers which are accessible from the top, using a hatch in the wash basket, are currently available, although DOE is unaware of any such CCWs on the market. For the purposes of this analysis, the terms "vertical-axis" and "top-loading" will be used interchangeably, as will the terms "horizontal-axis" and "front-loading." Additionally, clothes washers that have a wash basket whose axis of rotation is tilted from horizontal are considered to be horizontal-axis machines for the purposes of this analysis.

In the November 2007 ANOPR, DOE stated that it planned to consider a single product class for CCWs in accordance with the prescriptive standards for such equipment set in EPACT 2005. 72 FR 64432, 64465 (Nov. 15, 2007). Through EPACT 2005, Congress imposed a minimum energy efficiency threshold for all CCWs to meet. EPACT 2005 placed all CCWs into a single product class with a single energy efficiency and water efficiency standard for all covered equipment. *Id*. Accordingly, these standards encompass both top-loading and front-loading CCWs.

DOE has the authority to establish additional product classes within the CCW product category, if warranted. 72 FR 64432 (Nov. 15, 2007). In considering whether separate classes are warranted, DOE must consider the utility and performance characteristics to determine whether the relevant requirements have been met. (42 U.S.C. 6295(q); 6313(a)) Among the criteria DOE considered when examining potential separate product classes for clothes washers was the wash basket axis of rotation, which DOE also used for residential clothes washers. (See 10 CFR 430.32(g))

Although DOE considered issuing a single CCW product class in the ANOPR that would encompass both top-loading and front-loading CCWs, further consideration of the relevant statutory provisions and the public comments on the November 2007 ANOPR have led DOE to conclude that EPCA does not permit adoption of a standard that would eliminate top-loading CCWs. Accordingly, for the reasons explained below, DOE has decided to establish two classes of CCWs based upon axis of access (*i.e.*, top-loading or front-loading).

When directing the Secretary to consider amendments to the energy efficiency standards for CCWs, Congress did not mandate use of a single class or alter other relevant provisions of the statute related to setting classes. First, under 42 U.S.C. 6311(21), the definition of "commercial clothes washer" specifically includes both horizontal-axis clothes washers (front-loading machines) and vertical-axis clothes washers (top-loading machines). Further, the prescriptive standards for CCWs (1.26 Modified Energy Factor (MEF)/9.5 Water Factor (WF)), as set forth in 42 U.S.C. 6313(e), are achievable by both top-loading and front-loading machines. Neither provision indicates an intention to eliminate either type of CCW currently available.

Next, 42 U.S.C. 6295(o)(4)[c] provides, "The Secretary may not prescribe an amended or new standard … that is likely to result in the unavailability in the United States in any covered product type (or class) of performance characteristics (including reliability), features, sizes, capacities, and volumes that are substantially the same as those generally available in the United States at the time of the Secretary's finding." This statutory provision demonstrates congressional intent to forego potential energy savings under certain enumerated circumstances. DOE has determined that this provision applies to the present CCW rulemaking.

In previous rulemakings, DOE has concluded that the method of "loading" clothes in washers (axis of access) is a "feature" within the meaning of 42 U.S.C. 6295(o)(4) and, consequently, established separate product classes for top-loading and front-loading residential clothes washers. 56 FR 22263 (May 14, 1991). DOE reiterated this position in denying the California Energy Commission's (CEC) petition for waiver from Federal preemption of its residential clothes washer regulation.[d] 71 FR 78157 (Dec. 28, 2006). DOE denied the CEC petition for three separate and independent reasons, one of which was that "interested parties demonstrated by a preponderance of evidence that the State of California regulation would likely result in the unavailability of a class of residential clothes washers in California. … [T]he rule would violate EPCA in another way, *i.e.*, it would mandate the 6.0 WF standard in 2010, which would likely result in the unavailability of top-loader residential clothes washers." *Id*. at 78157-58. Given the similarities in technologies and design and operating characteristics between residential clothes washers and CCWs, in DOE's judgment, the axis of access must be accorded similar treatment in the context of the current CCW rulemaking.

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[c] This provision is also applicable to CCWs, pursuant to 42 U.S.C. 6316(a).

[d] DOE's denial of the CEC petition is currently in litigation (*California Energy Comm'n v. DOE*, No. 07-71576 (9th Cir. filed April 23, 2007)).

If DOE were to propose an amended standard for CCWs under the statutory criteria set forth in EPCA based upon a single product class, the result would be a standard that would effectively eliminate top-loading CCWs from the market, because it would set an MEF for all CCWs at a level significantly higher than the max-tech for top-loading machines. Because such a standard would violate the statute (42 U.S.C. 6295(o)(4); 6313(a)), DOE has decided to propose separate product classes and accompanying standards for top-loading and front-loading CCWs in the notice of proposed rulemaking (NOPR).

3.4 PRODUCT TEST PROCEDURES

Test procedures exist for all products covered by this rulemaking 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 residential cooking products and clothes washers through the rulemaking process. EPACT 2005 established a test procedure for CCWs.

DOE revised its test procedure for **cooking products** to more accurately measure their efficiency and energy use. For DOE's cooking products test procedure, DOE published the revisions as a final rule in 1997; these included: (1) a reduction in the annual useful cooking energy; (2) a reduction in the number of self-cleaning oven cycles per year; and (3) incorporation of portions of the International Electrotechnical Commission (IEC) Standard 705-1998 and Amendment 2-1993 (IEC 705) for the cooking performance testing of microwave ovens. (62 FR 51976, (October 3, 1997); 10 CFR part 430, subpart B, appendix I) Note that as of 1997, IEC has established a new numbering convention for standards. This test procedure has accordingly been assigned the publication number IEC 60705, and the current test procedure is IEC 60705 Edition 3.2-2006 (IEC 60705).[e]

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 ranges and ovens and 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 62301) and IEC standard 62087 *Methods of measurement for the power consumption of audio, video and related equipment*.[f] EPCA, as amended by the EISA, 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 notes that the current version of IEC 62301 is designated IEC 62301 Ed. 1.0-2005-06. DOE is also aware that IEC has proposed an updated standard, IEC 62301 Ed. 2.0, that amends the definitions of modes to include off mode(s), network connected standby mode(s), and disconnected mode as well as standby mode(s). However, this revision to IEC 62301 is not expected to be finalized until after the final rule is published for this overall rulemaking.

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[e] For more information visit http://www.iec.ch.

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

DOE believes separate test procedure rulemakings for standby mode and off mode power for microwave ovens and conventional cooking products are warranted. DOE does not have any data on standby power consumption in conventional cooking products that indicate the potential for significant energy savings. Thus, DOE will consider test procedure amendments in a later rulemaking that meets the March 31, 2011, deadline set by the EISA 2007 amendments to EPCA. (42 U.S.C. 6295(gg)(2)(B))

For microwave ovens, a test procedure change to incorporate standby mode and off mode power has been initiated in parallel with the current rulemaking, and a final rule for the test procedure is expected to be published prior to the publication of a final rule on energy conservation standards. DOE reviewed IEC 62301 as part of DOE's microwave oven power tests to determine whether the specified test conditions were suitable for microwave oven tests. The proposed test procedure would incorporate by reference provisions from IEC 62301 as well as language to clarify application of these provisions for measuring standby mode and off mode power where IEC 62301 is non-specific. The details of the test procedure change can be found in the separate microwave oven test procedure NOPR, which is being published in the *Federal Register*.

EPACT 2005 amended EPCA to require that **commercial clothes washers** be rated with the same test procedure established for residential clothes washers. (42 U.S.C. 6314(a)(8)) DOE adopted test procedures for CCWs in a final rule published on October 18, 2005. 70 FR 60407, 60416. DOE recognizes that the use of the residential clothes washer test procedure could provide an opportunity for CCW manufacturers to incorporate design options for which the residential clothes washer test procedure gives credit, but which are unlikely to save energy in CCWs or provide additional utility to consumers under actual operating conditions. For example, adaptive fill and load selector switches are unlikely to be used by CCW consumers, who generally pay a fixed fee per load and who are thus incentivized to run full-sized loads and/or select the maximum fill setting. While DOE believes commercial laundry practices likely differ from residential practices, DOE does not consider these differences to warrant the amendment of the CCW test procedure, since the characteristic energy and water use for CCWs are taken into account in the NOPR analyses. DOE recognizes that in certain situations, the controls and/or operation of a CCW can be such that certain design features (*e.g.*, fill level) can be set so that the CCW will not necessarily achieve the same energy and water savings that might be expected for residential clothes washers. However, DOE does not have sufficient usage data to alter its preliminary conclusion that the existing residential clothes washer test procedure is adequate to measure the energy consumption of CCWs.

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 cooking product and CCW industries, 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 several trade groups that support, or have an interest in, the residential cooking product and/or CCW industries, including the Association of Home Appliance Manufacturers (AHAM), the Coin Laundry Association (CLA), and the Multi-housing Laundry Association (MLA).

3.5.1 Association of Home Appliance Manufacturers

AHAM,[g] 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.

3.5.2 Coin Laundry Association

The CLA,[h] based in Downers Grove, Illinois, is a trade association representing the 30,000 coin laundry owners in the United States and around the world. Since 1960, the CLA has provided education and service to the entrepreneurs of the coin laundry industry, promoted their business interests, and promoted the industry to the general public.

3.5.3 Multi-housing Laundry Association

The MLA,[i] founded in 1959, is a trade association of operator and supplier companies providing professional laundry services for the multi-housing industry. The MLA works for a favorable legislative and regulatory climate for the industry, facilitates the exchange of technical and business information among members, and demonstrates the value of the industry to target markets.

3.6 MANUFACTURER INFORMATION

The following section details information regarding domestic manufacturers of residential cooking products and CCWs, 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).

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

[h] For more information visit http://www.coinlaundry.org.

[i] For more information visit http://www.mla-online.com.

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.

For **cooking products** (including ovens, cooktops, and ranges) DOE estimates that there are approximately 16 domestic manufacturers. As will be discussed in section 3.6.2, Maytag Corporation (Maytag) and Whirlpool Corporation (Whirlpool) merged in 2006 but have continued to maintain both product lines to this date. GE Consumer & Industrial (GE) and Whirlpool represent nearly three quarters of the electric range products market. GE represents over a third of the gas range products market, while the combined Whirlpool and Maytag comprise over a quarter. AB Electrolux (Frigidaire), Peerless-Premier Appliance Co. (Peerless-Premier), and other small manufacturers make up the difference in both markets. Figure 3.6.1 and Figure 3.6.2 illustrate the 2006 market shares for the domestic residential electric and gas range markets, respectively.

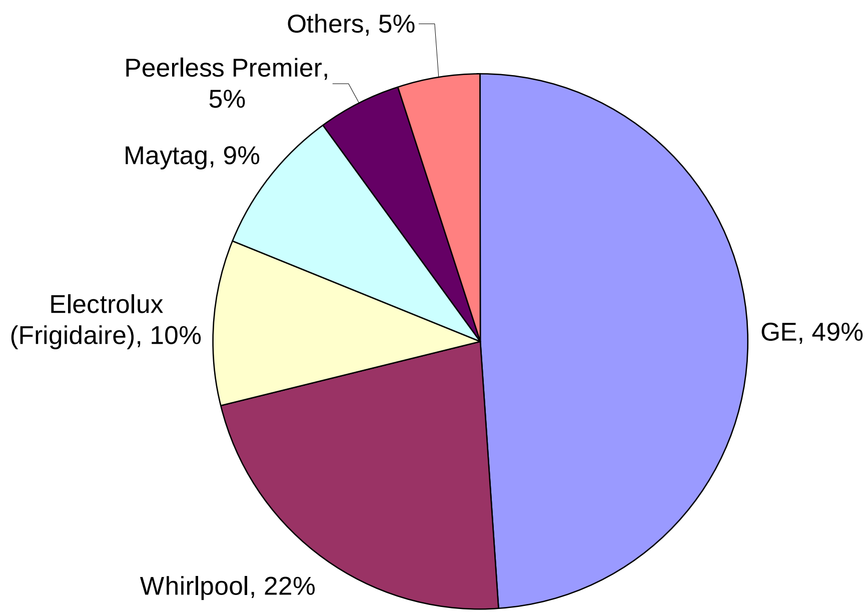


Figure 3.6.1 2006 Market Shares for the Domestic Electric Range Market[1]

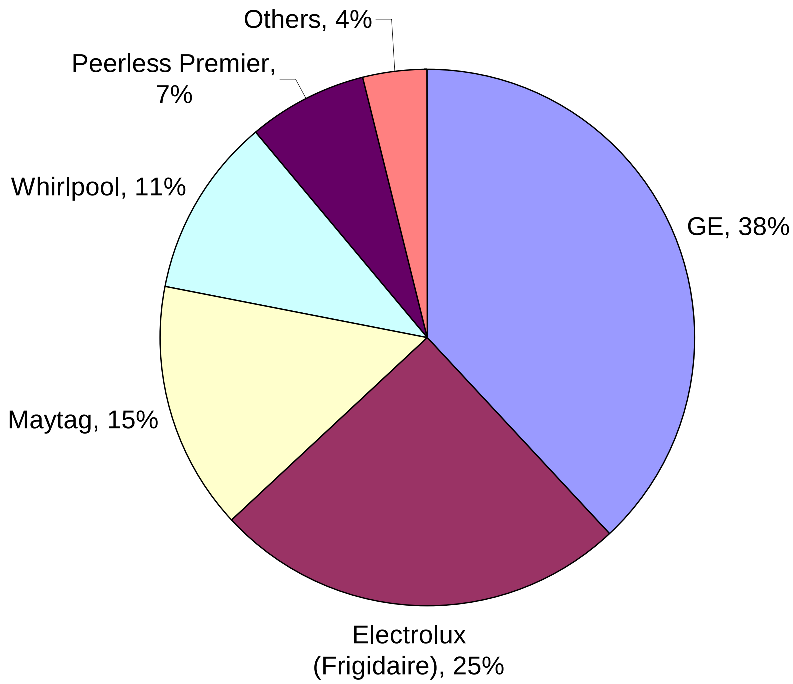


Figure 3.6.2 2006 Market Shares for the Domestic Gas Range Market[2]

In addition to the manufacturers presented above, manufacturers of **ovens**, **cooktops**, and **ranges** also include BSH Home Appliances Corporation (Bosch-Siemens) (which acquired Thermador Corporation), Dacor, Inc. (Dacor), De'Longhi America, Inc. (De'Longhi), Fagor America Inc. (Fagor), Fisher & Paykel Appliances Limited (Fisher & Paykel) (which acquired Dynamic Cooking Systems Inc.), Haier America Trading, LLC (Haier), Miele, Inc. (Miele), Kenyon International, Inc. (Kenyon), Sub-Zero Freezer Company, Inc. (Sub-Zero) (which acquired the residential division of the Wolf Appliance Company (Wolf)), Felix Storch, Inc. (Summit), and Viking Range Corporation (Viking). Table 3.6.1 lists these manufacturers.

Table 3.6.1 Major and Other Range, Oven and Cooktop Manufacturers

Major Manufacturers	Other Manufacturers
GE	Peerless-Premier
Whirlpool	Bosch-Siemens
Maytag	Dacor
Frigidaire	De'Longhi
	Fagor
	Fisher & Paykel
	Haier
	Miele
	Kenyon
	Sub-Zero
	Summit
	Viking

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 3.6.2 illustrates the 2006 market shares for the U.S. microwave oven market. Microwave oven manufacturers with facilities inside the United States include Maytag, the Sharp Electronics Corporation (Sharp), Sub-Zero, Summit, and Viking. Figure 3.6.3 lists microwave manufacturers active in the domestic market.

Table 3.6.2 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

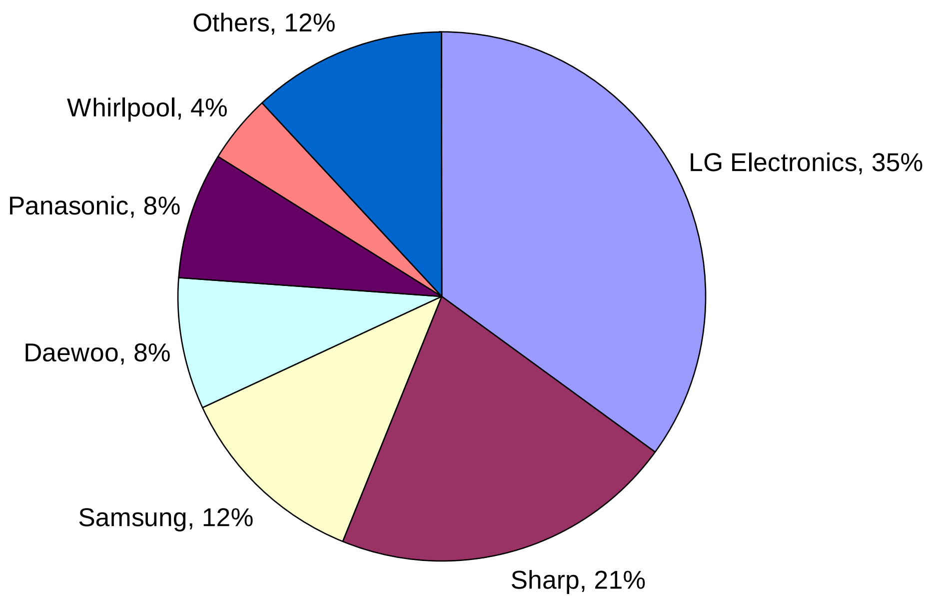


Figure 3.6.3 2006 Market Shares for the Domestic Microwave Oven Market[3]

For **commercial clothes washers**, DOE estimates that there are five domestic and three foreign manufacturers. The majority of market share is held by four major manufacturers, including Alliance Laundry Systems LLC (Alliance), Maytag, Whirlpool, and GE.[4] Other manufacturers include AB Electrolux (Electrolux)[j], Continental Girbau, Inc. (Continental), LG, and Bermil Industries Corporation (Wascomat). Table 3.6.3 lists these manufacturers.

Table 3.6.3 Major and Other Commercial Clothes Washer Manufacturers

Major Manufacturers	Other Manufacturers
Alliance	Electrolux
Maytag	Continental
Whirlpool	LG
GE	Wascomat

[j] Commercial clothes washers are marketed under the Electrolux Professional brand, as opposed to residential clothes washers which are primarily marketed under the Frigidaire brand.

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 September 2007 issue of *Appliance Magazine*, four manufacturers comprise 89 percent of the core appliance market share. "Core appliances" include dishwashers, clothes dryers, freezers, ranges, refrigerators, and clothes washers. Table 3.6.4 lists these core appliance manufacturers, and Figure 3.6.4 illustrates the breakdown of 2006 market shares in the core appliance category.

Table 3.6.4 Core Appliance Manufacturers

Core Appliance Manufacturers
Whirlpool
GE
Frigidaire
Maytag

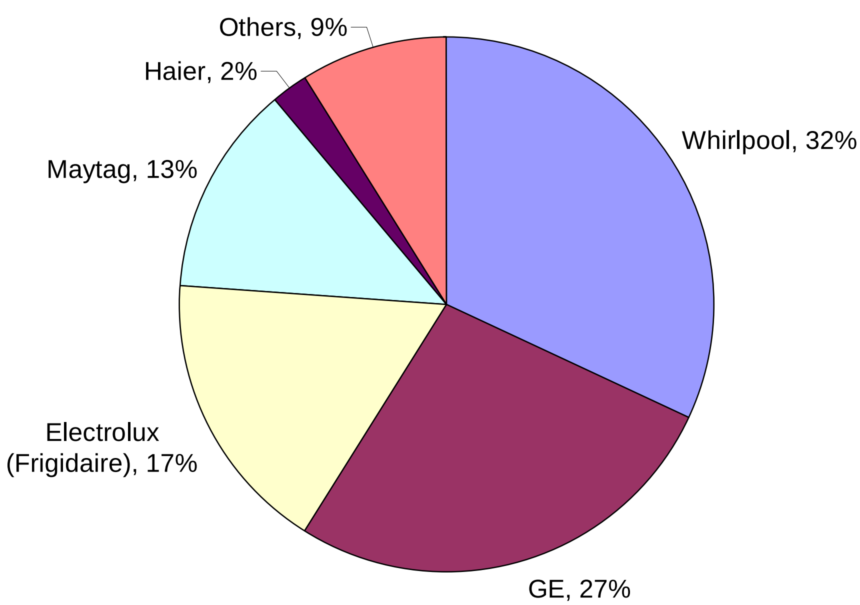


Figure 3.6.4 2006 Core Appliance Market Shares[5]

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.[6] 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.[7] 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.[8]

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."[9]

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."[10]

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.[11]

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 and CCWs. At this time, DOE is aware of two small cooking products 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. DOE evaluated the potential impacts on these small businesses as part of the manufacturer impact analysis (MIA), which it conducted as a part of the NOPR analysis. For CCWs, manufacturers with 500 or fewer employees are classified by the SBA as small businesses. DOE is unaware of any such CCW manufacturers. For further information on the cooking products small businesses, see chapter 13 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 and CCWs from publicly available sources. This section contains distribution channel information for residential appliances and CCWs.

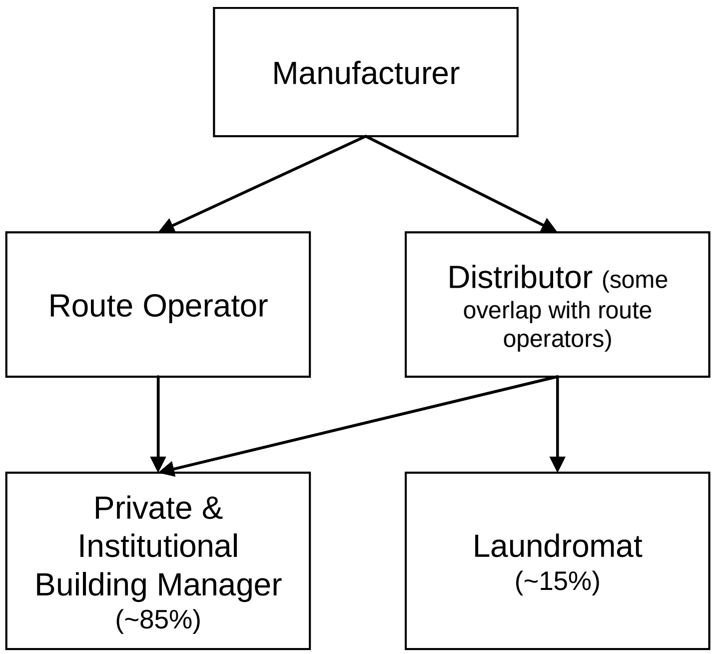
The distribution chain for residential appliances, including **cooking products**, differs from commercial products, as the majority of consumers purchase their appliances directly from retailers. These retailers include: (1) home improvement, appliance, and department stores; (2) Internet retailers; (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.[12]

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.[13]

For **commercial clothes washers**, DOE used a 1998 Consortium for Energy Efficiency (CEE) report describing their Commercial, Family-Sized Clothes Washer Initiative (see section 3.8.1 of this TSD).[14] This report includes an assessment of the CCW market. Figure 3.6.5 illustrates the CCW distribution channels identified in this report, which DOE believes are representative of the current market as well.

CEE reports that the CCW market can be divided into three areas, including: (1) laundromats; (2) private multi-family housing; and (3) large institutions (*e.g.*, military barracks, universities, and housing authorities.) Most large institutions and a majority of private multi-family housing (between 50 and 90 percent) do not purchase clothes washers directly. Rather, these organizations lease their laundry space to a third party known as a route operator. Route operators supply laundry equipment and maintain facilities in exchange for a percentage of the laundry revenue. Laundromats and some private building managers, conversely, will purchase clothes washers directly from distributors. The main difference between route operators and distributors is the length of service provided to their clients. Route operators provide on-going support while distributor support ends at the point of sale.[15]

According to CEE's report, there are between 2 and 3 million CCWs installed in the United States. In general, these washers are replaced at a rate of 10 percent per year, resulting in a replacement of approximately 200,000 to 300,000 washers annually. In its 2007 CCW data submittal, AHAM reported somewhat lower shipment volumes of 175,000 to 190,000 units per year from 2002–2005. CEE also reports that, of this annual replacement total, approximately 15 percent go to laundromats while 85 percent go to the multi-family sector.[16]



Source: CEE, Commercial, Family-Sized Washers: An Initiative Description of the Consortium for Energy Efficiency, 1998.

Figure 3.6.5 Commercial Clothes Washer Distribution Channels

3.7 REGULATORY PROGRAMS

The following section details current regulatory programs mandating energy conservation standards for residential cooking products and CCWs. Section 3.7.1 discusses Federal energy conservation standards prior to EPACT 2005, section 3.7.2 reviews new standards issued by EPACT 2005, section 3.7.3 reviews upcoming standards under EISA 2007, and section 3.7.4 provides an overview of existing State standards. In addition, section 3.7.5 reviews standards in Canada that may impact the companies servicing the North American market.

3.7.1 Federal Energy Conservation Standards Prior to EPACT 2005

The National Appliance Energy Conservation Act of 1987 (NAECA) (42 U.S.C. 6291-6309) amended EPCA to establish prescriptive standards for gas **cooking products**, requiring gas ranges and ovens with an electrical supply cord not to be equipped with constant burning pilots and directed DOE to conduct two cycles of rulemakings to determine if more stringent standards are justified. (42 U.S.C. 6295 (h)(1)-(2)) DOE initially analyzed standards for cooking products as part of an eight-product standards rulemaking. It issued a NOPR on March 4, 1994, proposing performance standards for gas and electric residential cooking products, including microwave ovens. 59 FR 10464. In accordance with its *Procedures for Consideration of New or Revised Energy Conservation Standards for Consumer Products* (the "Process Rule") (61 FR 36974 (July 15, 1996); 10 CFR part 430, subpart C, appendix A), DOE refined its standards analysis of cooking products. With regard to gas cooking products, DOE focused on the economic justification for eliminating standing pilots. Partially due to the difficulty of conclusively demonstrating that elimination of standing pilots was economically justified, DOE issued a final rule on September 8, 1998, that covered only electric cooking products, including microwave ovens. 63 FR 48038. The final rule found that standards were not economically justified for electric cooking products. DOE never completed its standards rulemaking for gas cooking products.

3.7.2 Energy Policy Act of 2005

On August 8, 2005, the President signed into law EPACT 2005. This legislation established energy conservation standards for several residential and commercial products, including **commercial clothes washers**. Without consideration for product classes, section 136(e) of EPACT 2005 amends section 342 of EPCA, 42 U.S.C. 6313, to add subsection (e) for CCWs, which establishes energy and water conservation standards. These Federally mandated standards for CCWs became the national standards when they took effect on January 1, 2007. Table 3.7.1 provides EPACT 2005 standards for CCWs.

Table 3.7.1 EPACT 2005 Standards for Commercial Clothes Washers

Clothes Washer Classification	Standards Effective January 1, 2007	
	MEF* (ft^3/kWh/cycle)	WF* (gallons/ ft^3/cycle)
Top- and front-loading	1.26	9.5

*The Modified Energy Factor (MEF), is a measure of how many kilowatt-hours (kWh) are required to wash each cubic foot (ft^3) of washer capacity. It measures the total energy consumption of the washer and also accounts for the amount of energy required to dry clothes based on the remaining moisture content of the clothes. Water Factor (WF) is measured in gallons of water required per cycle per cubic foot of washer capacity.

New subsection 342(e), 42 U.S.C. 6313(e) also requires that DOE issue a final rule by January 1, 2010, to determine whether these standards for CCWs should be amended.

3.7.3 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 325 of EPCA is amended by section 310 of EISA

2007 to require DOE to regulate standby mode and off mode energy consumption as part of an energy conservation standard for all covered products, including residential **ranges and ovens** and **microwave ovens**, for which a final rule is adopted after July 10, 2010. (42 U.S.C. 6295(gg)(1)(A)) Off mode is defined by EISA 2007 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 EISA 2007 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))

Because the final rule for this rulemaking is scheduled to be published in the *Federal Register* by March 31, 2009, an energy conservation standard for cooking products set forth by this rulemaking is not required to incorporate standby mode and off mode energy consumption. Although DOE is also not required to incorporate standby mode and off mode energy consumption for any cooking products at this time, in the November 2007 ANOPR, DOE 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. Such a test procedure change is a prerequisite to incorporate a standby power requirement as part of the energy conservation standard for microwave ovens.[k] 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 NOPR to put forth standards for microwave oven standby power only, but remains open to consideration of off-mode standards.

As stated previously, DOE does not have any data on standby power consumption in conventional cooking products (*i.e.*, electric and gas cooktops and ovens) that indicate the potential for significant energy savings. For this reason, DOE is not considering regulating standby and off-mode power for conventional cooking products as part of the current rulemaking.

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[k] As discussed in the November 2007 ANOPR, addressing standby mode and off mode energy consumption is not required for this rulemaking under EPCA, but DOE seeks to publish a final rule for the test procedure amendments prior to March 31, 2009, in order to allow the microwave oven energy conservation standards to account for standby mode and off mode power.

3.7.4 State Energy Conservation Standards

Prior to the passage of EPACT 2005, several States proposed and adopted State-level efficiency regulations for **commercial clothes washers** that are identical, or very similar, to EPACT 2005 regulations. The EPACT 2005 energy and water use standards for CCWs preempt any State efficiency standards since they became effective January 1, 2007. Table 3.7.2 presents information regarding States adopting CCW standards comparable to EPACT 2005.

Table 3.7.2 State Commercial Clothes Washer Regulations Similar to EPACT 2005

State	Effective Date	Difference from EPACT 2005
Arizona	MEF and WF: 1/1/08	Standards effective one year later than EPACT 2005
California	MEF: 1/1/05 WF: 1/1/07	MEF standard effective two years earlier than EPACT 2005
Connecticut	MEF and WF: 7/1/06	Standards effective six months earlier than EPACT 2005
Maryland	MEF and WF: 3/1/07	Standards effective two months later than EPACT 2005
New Jersey	MEF: 1/1/07 WF: 1/1/10	Water factor standard effective three years later than EPACT 2005
Oregon	MEF and WF: 1/1/08	Standards effective one year later than EPACT 2005
Rhode Island	MEF and WF: 1/1/07	Identical to EPACT 2005
Washington	MEF - For Sale: 1/1/07 MEF - Installation: 1/1/08	Does not address water factor

As presented in the table above, the State of California mandates energy and water conservation standards for commercial front-loading and commercial top-loading automatic clothes washers. Table 3.7.3 provides the State's CCW energy conservation standards, which are dependent on clothes container capacity, and the water conservation standards, which became effective two years after the MEF standards.

Table 3.7.3 California State Efficiency Standards for Commercial Clothes Washers

Clothes Washer Classification	Clothes Container Compartment Capacity (ft^3)	Minimum MEF Effective January 1, 2005	Maximum WF Effective January 1, 2007
Front-loading	< 3.5 ft^3	1.26	9.5
Top-loading	< 1.6 ft^3 ≥ 1.6 ft^3 and < 4.0 ft^3	0.65 1.26	9.5 9.5

In addition to the efficiency standards discussed above, the State of California requires that commercial top-loading semi-automatic clothes washers and commercial suds-saving clothes washers manufactured on or after January 1, 2005, have an unheated rinse water option.

Additionally, California issued minimum water conservation standards for residential clothes washers. While this does not directly affect products covered by the rulemakings, DOE is aware that this standard may have impacts on manufacturers of CCWs and other household appliances. Although Federal standards exist for the energy consumption of residential clothes washers, no such standard exists for the water efficiency. On September 16, 2005, the California Energy Commission (CEC) issued a petition for an exemption from Federal preemption to seek to apply its own State regulation for residential clothes washer WF. DOE accepted written comments regarding this California petition until April 7, 2006. Table 3.7.4 provides the State's proposed residential clothes washer water conservation standards and their respective effective dates.

Table 3.7.4 California Water Conservation Standards for Residential Clothes Washers

Clothes Washer Classification	Maximum WF	
	Effective January 1, 2007	Effective January 1, 2010
Top-loading	8.5	6.0
Front-loading	8.5	6.0

On December 28, 2006, DOE issued a decision denying the California petition. 71 FR 78157. The denial of the petition was based on three factors. First, DOE determined that it does not have the statutory authority to prescribe a rule for California that would become effective by January 1, 2007, the first of two compliance dates contained in Title 20, section 1605.2(p)(1) of the California Code of Regulations. Second, DOE ruled that the CEC had not established by a preponderance of the evidence that the State of California has unusual and compelling water interests, a condition required by EPCA for DOE to grant California a waiver from Federal preemption. (42 USC 6297(d)(1)(B)) Finally, a preponderance of evidence showed that the California regulation would likely result in the unavailability of a class of residential clothes washers, specifically top-loader machines, in California. The State has submitted to DOE a request for reconsideration.[17]

3.7.5 Canadian Energy Conservation Standards

Canada's Energy Efficiency Regulations (hereafter Regulations) mandate minimum energy conservation standards for certain residential **cooking products**, including electric and gas ranges, cooktops, and ovens. The Regulations do not cover microwave ovens. Like U.S. DOE standards, Canadian Regulations require that gas cooking products, including ranges, ovens, and cooktops, with an electrical supply cord not be equipped with constant burning pilots. Table 3.7.5 presents the Regulations for electric cooking products.

Table 3.7.5 Canadian Energy Conservation Standards for Electric Cooking Products

Cooking Product Classification	Maximum Allowable Energy Consumption (kWh/year)*
Free-standing or built-in ranges with one or more surface elements and one or more ovens	2.0V + 458
Built-in or wall-mounted ranges without surface elements and with one or more ovens	2.0V + 200
Counter-mounted ranges without ovens and with one or more surface elements on a conventional (*i.e.*, not modular) cooktop	258

* Where V = volume of oven in liters

The Canadian government also regulates the efficiency of residential **clothes washers**. While this standard does not directly apply to products covered by this rulemaking, DOE understands that this standard may still impact some North American manufacturers in the home appliance industry. This Regulation applies to standard or compact electrically operated household clothes washers that are top- or front-loaded, and that have an internal control system that regulates the water temperature without the need for user intervention subsequent to initiation of machine operation. Table 3.7.6 lists the current standards that went into effect January 1, 2007, along with the previous standards that went into effect January 1, 2004.

Table 3.7.6 Canadian Energy Conservation Standards for Residential Clothes Washers

Clothes Washer Classification	Minimum MEF (L/kWh/cycle)	
	January 1, 2004	**January 1, 2007**
Vertical-axis compact (< 45 liter capacity)	18.40	18.40
Vertical-axis standard (≥ 45 liter capacity)	29.45	35.68
Horizontal-axis*	29.45	35.68
Suds-saving*	NA	NA

* These product classes shall be equipped with an unheated rinse water option.

3.7.6 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 watt (W) requirement for all consumer electrical products (unless specifically excluded) in standby mode. The IEA also stated that IEC 62301 provides an internationally sanctioned definition and test procedure for standby power, which is now widely specified and used.[l]

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 for all consumer electrical products by 2012, including microwave ovens.[18] 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. The program is currently transitioning to a mandatory 1 W standard by the year 2010.[19] In accordance with Japan's Top Runner Program,[m] 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.[20]

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

[m] 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*

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 July 23, 2008, the Commission of the European Communities published a draft proposal containing Ecodesign requirements for standby and off mode electric power consumption. Table 3.7.7 presents the proposed criteria for standby and off mode power, which are well in line with the IEA 1-Watt plan.[21]

Table 3.7.7 Proposed EU Ecodesign requirements for standby and off mode

Mode	Maximum Power Watts
Tier 1 (1 year after implementing measure has come into force)	
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 (4 years after implementing measure has come into force)	
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 several voluntary programs promoting energy efficient residential cooking products and CCWs in the United States. Many programs, including the CEE, ENERGY STAR, and FEMP, establish voluntary energy conservation standards for these products.

3.8.1 Consortium for Energy Efficiency

The CEE[n] develops initiatives for its North American members to promote the manufacture and purchase of energy efficient products and services. The goal of the organization is to induce lasting structural and behavioral changes in the marketplace, resulting in the increased adoption of energy efficient technologies.

In 1998, CEE launched the Commercial, Family-Sized Washer Initiative as an offshoot of its Residential Clothes Washer Initiative. The initiative encourages the purchase and use of energy and water efficient **commercial clothes washers** for laundromats, multi-family buildings and institutions. Table 3.8.1 presents the current voluntary efficiency specifications for the program. In order to qualify, a CCW must exceed the minimum MEF and remain below a specified WF.

[n] For more information visit http://www.cee1.org.

Table 3.8.1 CEE Criteria for Commercial Clothes Washers

Level	MEF	WF
Tier 1	1.80	7.5
Tier 2	2.00	6.0
Tier 3	2.20	4.5

3.8.2 ENERGY STAR

ENERGY STAR, a voluntary labeling program backed by the U.S. Environmental Protection Agency (EPA) and DOE, identifies energy efficient products through a qualification process.[o] To qualify, a product must exceed Federal minimum standards by a specified amount, or if no Federal standard exists, exhibit selected energy saving features. The ENERGY STAR program works to recognize the top quartile of products on the market, meaning that approximately 25 percent of products on the market meet or exceed the ENERGY STAR levels. ENERGY STAR specifications exist for several products, including CCWs.

ENERGY STAR criteria exist for top- and front-loading **commercial clothes washers** with capacities greater than 1.6 cubic feet. New ENERGY STAR criteria for CCWs, which include energy and water consumption ratings, became effective January 1, 2007. The current criteria and previous criteria are contained in Table 3.8.2.

Table 3.8.2 ENERGY STAR Criteria for Commercial Clothes Washers

Clothes Washer Classification	Previous Criteria Level	Current Criteria Levels
Top- and front-loading clothes washers	MEF ≥ 1.42	MEF ≥ 1.72 WF ≤ 8.0

3.8.3 Federal Energy Management Program

DOE's FEMP[p] 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. FEMP helps Federal buyers identify and purchase energy efficient equipment, including microwave ovens and CCWs.

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.

[o] For more information visit http://www.energystar.gov.

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

Table 3.8.3 FEMP Recommendations for Microwave Ovens

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

* Based on test procedures specified in IEC 62301

For **commercial clothes washers**, FEMP issues energy efficiency recommendations based on washer volume. Table 3.8.4 presents the CCW recommendations.

Table 3.8.4 FEMP Recommendations for Commercial Clothes Washers

Clothes Washer Tub Volume	Annual Energy Use (kWh/yr)*	MEF
1.9 - 2.5 ft^3	410 or less	2.5 or higher
2.6 – 3.3 ft^3	520 or less	2.5 or higher

* Based on 392 wash cycles per year (10 CFR part 430, subpart B, appendix J1)

FEMP estimates that, with electric water heating, replacing a 2.48 ft^3 CCW exhibiting an MEF of 1.80 with a clothes washer exhibiting an MEF of 2.50 will save $1,400 over the lifetime of the unit (assuming Federal average energy prices). The same replacement with gas water heating will save $800 over the lifetime of the clothes washer.

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, EPA, and AHAM to evaluate residential appliance product shipment trends and the value of these shipments, which were used during the shipments analysis (chapter 10 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 cooking products, these products are also fixtures in virtually all new homes. Multi-family unit starts can also affect shipments of CCWs.

Figure 3.9.1 presents the number of new single-family and multi-family housing units started in the United States from 1998–2007. 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 2007, single-family home starts decreased 39.0 percent, to 1,046,000 units annually. Multi-family unit starts have remained relatively flat over the past 10 years, hovering around 350,000 units annually.[22]

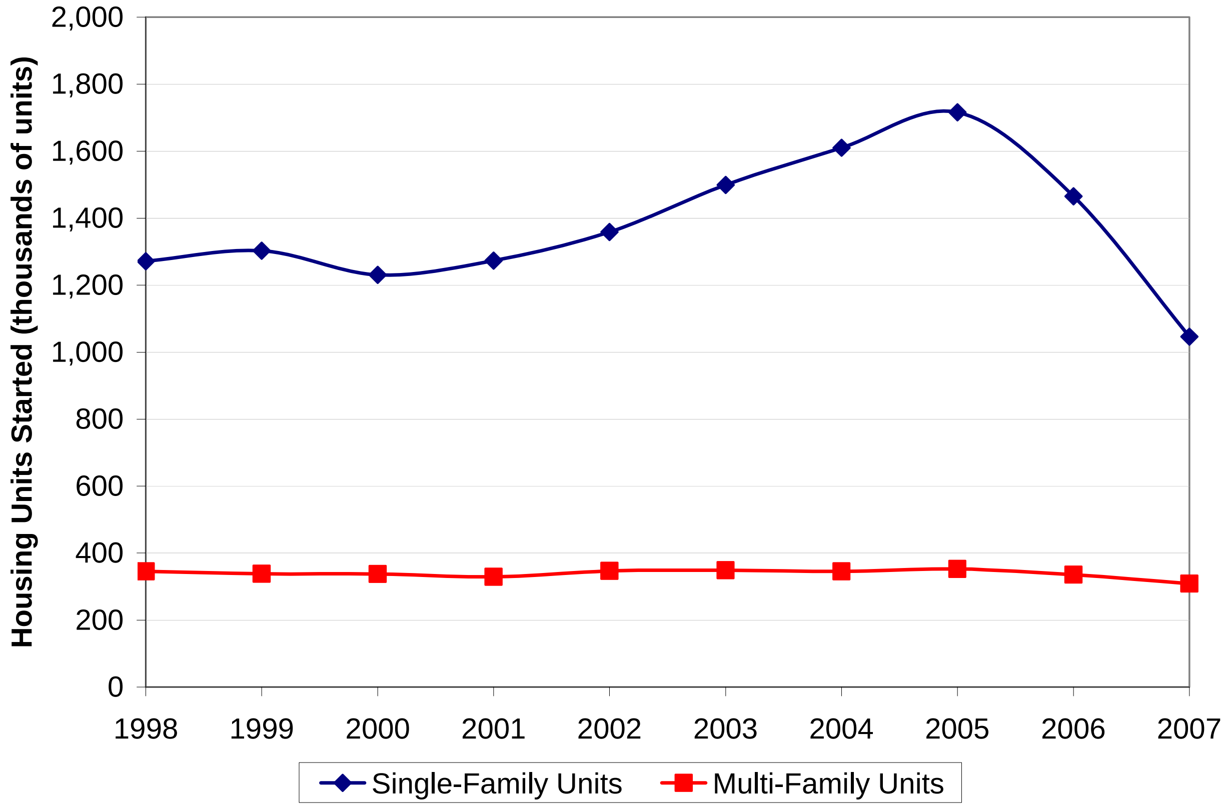

Figure 3.9.1 New Privately Owned Single-Family and Multi-Family Housing Unit Starts in the United States from 1998–2007 [23]

3.9.2 Unit Shipments

AHAM's *Fact Book* provides annual unit shipments for residential appliances. Table 3.9.1 presents annual shipments of **cooking products**. In the 10-year period from 1995–2005, shipments of electric and gas free-standing ranges and surface cooking units, electric built-in ranges, and microwave ovens increased, while shipments of built-in gas ranges decreased.

Table 3.9.1 Industry Shipments of Cooking Products (Domestic and Import in Thousands of Units) [24]

Year	Cooking Products								
	Electric Ranges				Gas Ranges				Microwave Ovens
	Free-Standing	Built-In	Surface Cooking Units	Total	Free-Standing	Built-In	Surface Cooking Units	Total	
2005	4,685	973	542	6,201	3,139	64	560	3,762	13,862
2004	4,612	963	570	6,145	3,124	67	528	3,719	15,526
2003	4,238	841	543	5,622	2,897	67	455	3,419	14,274
2002	4,030	780	528	5,338	2,781	71	416	3,268	13,311
2001	3,842	726	498	5,066	2,580	72	384	3,036	13,446
2000	3,826	706	494	5,026	2,729	70	377	3,176	12,644
1999	3,785	705	493	4,983	2,698	72	367	3,137	11,422
1998	3,481	652	506	4,639	2,543	71	336	2,950	10,365
1997	3,177	617	446	4,240	2,391	73	280	2,744	8,883
1996	3,123	614	418	4,155	2,366	72	272	2,710	8,771
1995	2,931	598	389	3,917	2,391	84	240	2,715	8,162

ENERGY STAR shipment data for residential **clothes washers** may also prove useful during this standards rulemaking. Table 3.9.2 presents the 2005 breakdown of ENERGY STAR versus non-ENERGY STAR shipments for residential clothes washers.

Table 3.9.2 2005 ENERGY STAR Shipments by Product (Domestic and Import)

Product	Shipments			% ENERGY STAR of Total[25]
	ENERGY STAR-Qualified	Other	Total[26]	
Residential Clothes Washers	3,424,000	5,970,000	9,394,000	36.5

3.9.3 Value of Shipments

Table 3.9.3 provides the value of shipments for the household appliance industry from 1994–2006 based upon data from the U.S. Census Bureau's *Annual Survey of Manufacturers* (ASM).[q] The ASM expresses all dollar values in nominal dollars; *i.e.*, 2006 data are expressed in 2006 dollars, and 2005 data are expressed in 2005 dollars. Using the Gross Domestic Product Implicit Price Deflator, DOE converted each year's value of shipments to 2006 dollars. In constant 2006 dollars, the value of shipments has declined by nearly 22 percent over the 13-year period.

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

Table 3.9.3 Household Appliance Manufacturing Statistics by Year[27]

Year	Value of Shipments in Nominal Dollars ($1000)	Value of Shipments in 2006 Dollars ($1000)
2006	22,965,146	22,965,146
2005	24,620,117	25,341,881
2004	23,989,141	25,439,547
2003	23,026,196	25,111,893
2002	22,269,541	24,803,498
2001	22,298,897	25,269,862
2000	23,414,965	27,171,194
1999	22,372,219	26,526,720
1998	22,471,878	27,030,451
1997	21,394,445	26,019,810
1996	22,156,900	27,395,591
1995	22,391,300	28,210,228
1994	22,793,900	29,305,108

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 3.9.4 presents the various methods by which consumers dispose of their older appliances.

Table 3.9.4 Disposition of Previous Appliance (Percentage)[28]

Product	Kept It	Left with Previous Home	Sold / Gave Away	Recycling Facility	Left at Curb for Disposal	Retailer Took Away
Ranges	6	37	21	13	8	15
Built-In Ranges	4	46	11	15	12	13
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 13 years when viewed in 2006 real dollars. Overall, the real value of shipments in 2006 was less than one percent lower than the value in 1994. Table 3.9.5 provides the industry value of shipments for household cooking appliance manufacturing.

Table 3.9.5 Household Cooking Appliance Manufacturing Statistics by Year[29]

Year	Value of Shipments in Nominal Dollars ($1000)	Value of Shipments in 2006 Dollars ($1000)
2006	4,864,268	4,864,268
2005	5,114,677	5,264,619
2004	4,798,227	5,088,332
2003	4,691,713	5,116,685
2002	4,327,308	4,819,694
2001	3,773,442	4,276,192
2000	4,178,958	4,849,346
1999	3,915,499	4,642,604
1998	3,849,167	4,629,997
1997	3,520,635	4,281,778
1996	3,564,700	4,407,524
1995	3,788,200	4,772,657
1994	3,813,900	4,903,362

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 1.0 percent in 2007 as compared to 2006. Major appliance unit exports increased 5.2 percent over the same period.

Table 3.9.6 shows selected import data from AHAM's *2007 Preliminary Year End Import/Export Trade Report*.[30] For microwave ovens less than or equal to 22.5 inches in width, the number of units decreased, while the value of units increased. For microwave ovens 22.5 inches to 31.0 inches in width and coin-operated washing machines, both the number and value of units imported increased from 2006–2007. For non-portable cooking products and electric stoves, ranges, and ovens, the number of units imported decreased over the 1-year period, while the value of those units increased. For microwave ovens less than 22.5 inches and greater than 31.0 inches in width, both the number and value of units imported decreased. Overall, the value of major appliance imports increased 4.7 percent from 2006–2007.

Table 3.9.6 2006–2007 Imports of Appliances Covered by this Rulemaking[31]

Appliance Description	Jan. – Dec. 2007	Jan. – Dec. 2006	% Change	Jan. – Dec. 2007	Jan. – Dec. 2006	% Change
	Units			$ Mil (Nominal)		
Non-portable cooking products	1,305,336	1,384,498	-5.7	371.312	351.130	5.7
Coin-operated washing machines	4,581	2,113	116.8	7.242	3.279	120.9
Microwave ovens ≤ 22.5 inches	5,773,979	6,006,978	-3.9	180.046	189.020	-4.7
Microwave ovens > 22.5-31.0 inches	4,093,919	3,793,086	7.9	196.056	174.112	12.6
Microwave ovens > 31.0 inches	7,188,969	7,649,158	-6.0	634.512	679.261	-6.6
Electric stoves, ranges, and ovens	2,554,770	2,813,383	-9.2	488.650	453.341	7.8

Table 3.9.7 shows selected export data from AHAM's *2007 Preliminary Year End Import/Export Trade Report*.[32] For the 1-year period from 2006–2007, both the number and value of unit exports of non-portable cooking products and electric stoves, ranges, and ovens increased. For the same time period, the number of coin-operated washing machines and microwave oven exports decreased, but the value of those exports increased. Overall, the total value of exports increased 5.6 percent.

Table 3.9.7 2004–2005 Exports of Appliances Covered by this Rulemaking [33]

Appliance Description	Jan. – Dec. 2007	Jan. – Dec. 2006	% Change	Jan. – Dec. 2007	Jan. – Dec. 2006	% Change
	Units			$ Mil (Nominal)		
Non-portable cooking products	122,460	107,706	13.7	68.544	58.845	16.5
Coin-operated washing machines	88,382	95,246	-7.2	41.202	40.054	2.9
Microwave ovens	299,981	303,229	-1.1	36543	35.304	3.5
Electric stoves, ranges, and ovens	481,286	453,002	6.2	272.619	258.182	5.6

3.10 MARKET SATURATION

AHAM's *Fact Book 2005* presents the market saturation for **cooking products**. While the percentage of U.S. households with electric ranges and/or cooktops and microwave ovens has decreased slightly since 2001, the market saturation of gas cooking products has increased. Table 3.10.1 presents the appliance saturation and percentage of U.S. households with each product as reported in the AHAM *Fact Book 2005*. The number of U.S. households with each product 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 [34]

Product	1970		1982		1990		2001		2005	
	#	%	#	%	#	%	#	%	#	%
Electric Ranges / Cooktops*	25.8	40.6	48.4	58	58.4	62.6	69.2	66.3	71	65.3
Gas Ranges / Cooktops*	36.6	57.7	35.7	42.7	36.1	38.7	39.4	37.8	42.2	39
Microwave Ovens	Neg.	Neg.	21.4	25.6	77.2	82.7	94.6	90.7**	97.2	89.3

* Cooktops not included in 1970 or 1982 data
** 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 several residential appliances and the Consumer Price Index (CPI) of each year (1982–84 = 100). Although prices for electric and gas ranges have increased since 1980, the increase has been at a much slower rate than the annual rate of inflation. Prices of microwave ovens and automatic clothes washers have decreased in the same time period.

Table 3.11.1 Residential Appliance Retail Prices [35]

Product	Average Retail Prices (Nominal $)				Percent Change
	1980	1994	2002	2005	1980–2005
Electric Ranges	412	503	508	444	7.8%
Gas Ranges	380	499	497	462	21.6%
Microwave Ovens	450	239	145	99	-78.0%
Automatic Clothes Washers	386	394	426	359	-7.0%
*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.

In the above table, automatic clothes washers pertain to residential clothes washers, not CCWs. As a result, DOE conducted a limited search of consumer retail prices for CCWs by telephoning five commercial laundry distributors and gathering data from four Internet retailers. Table 3.11.2 summarizes the data collected by DOE. Most of the distributors and Internet retailers provided a range of prices for each washer model. Only the average price for each model is provided in the table below.

Table 3.11.2 Commercial Clothes Washer Retail Prices

Source	Source Type	Manufacturer	Brand	Model Number	Coin Box	Loading	Axis	Average Price
AbsoluteHome.com[36]	Internet	Whirlpool	Whirlpool	CAM2752RQ	Yes	Top-Load	Vertical	$749
AbtElectronics.com[37]	Internet	General Electric	Roper	RAK2751WWH	Yes	Top-Load	Vertical	$597
AbtElectronics.com	Internet	Whirlpool	Whirlpool	CAM2752WH	Yes	Top-Load	Vertical	$688
AbtElectronics.com	Internet	Whirlpool	Maytag	MAT12CSWH	Yes	Top-Load	Vertical	$898
AJMadison.com[38]	Internet	Whirlpool	Whirlpool	CAM2752RQ	Yes	Top-Load	Vertical	$689
Commercial & Coin Laundry Equip.[39]	Distributor	Whirlpool	Whirlpool	N/A	Yes	Top-Load	Vertical	$700
Commercial & Coin Laundry Equip.	Distributor	Alliance	Speed Queen	N/A	Yes	Top-Load	Vertical	$775
Commercial Laundry Equipment[40]	Distributor	Alliance	Speed Queen	SWTBA1WN	Yes	Top-Load	Vertical	$965
Gold Coin Laundry Equipment[41]	Distributor	General Electric	General Electric	WCCB1030F	Yes	Top-Load	Vertical	$900
Gold Coin Laundry Equipment	Distributor	General Electric	General Electric	WCCB2050	Yes	Top-Load	Vertical	$920
Mac-Gray Services[42]	Distributor	Whirlpool	Maytag	MAT12PDSWW	Yes	Top-Load	Vertical	$895
Texas Laundry Service[43]	Distributor	Alliance	Speed Queen	JWT110, SWTB20	Yes	Top-Load	Vertical	$1,113
AbtElectronics.com	Internet	Frigidaire	Frigidaire	FCCW3000WH	Yes	Front-Load	Horizontal	$949
Commercial Laundry Equipment	Distributor	Alliance	Speed Queen	SWFB61WN	Yes	Front-Load	Horizontal	$1,462
Gold Coin Laundry Equipment	Distributor	General Electric	General Electric	WCCH404VWW	Yes	Front-Load	Horizontal	$1,500
Laundry Systems[44]	Internet	Electrolux	Wascomat	WE16	Yes	Front-Load	Horizontal	$1,074
Mac-Gray Services	Distributor	Whirlpool	Maytag	MAH21PDAWW	Yes	Front-Load	Horizontal	$1,450
Texas Laundry Service	Distributor	Alliance	Speed Queen	SWRF961, SWFB63	Yes	Front-Load	Horizontal	$1,695
AbsoluteHome.com	Internet	General Electric	General Electric	WNRD2050DWC	No	Top-Load	Vertical	$649
AbtElectronics.com	Internet	Whirlpool	Maytag	MAT13MNWH	No	Top-Load	Vertical	$769
AJMadison.com	Internet	General Electric	General Electric	WNRD2050D	No	Top-Load	Vertical	$529
Commercial & Coin Laundry Equip.	Distributor	N/A	N/A	N/A	No	Top-Load	Vertical	$850
Commercial Laundry Equipment	Distributor	Alliance	Speed Queen	LWF02N	No	Top-Load	Vertical	$531
Gold Coin Laundry Equipment	Distributor	General Electric	General Electric	WNRD2050D	No	Top-Load	Vertical	$710
Mac-Gray Services	Distributor	Whirlpool	Maytag	MAT12PN	No	Top-Load	Vertical	$795
Texas Laundry Service	Distributor	Alliance	Speed Queen	LWS01, LWS49	No	Top-Load	Vertical	$740
Commercial & Coin Laundry Equip.	Distributor	Alliance	Speed Queen	N/A	No	Front-Load	Horizontal	$1,400
Commercial Laundry Equipment	Distributor	Alliance	Speed Queen	LTF90AWM	No	Front-Load	Horizontal	$1,229
Laundry Systems	Internet	Frigidaire	Wascomat	WE16	No	Front-Load	Horizontal	$923
Laundry Systems	Internet	Alliance	Huebsch	FTZ91AWN11	No	Front-Load	Horizontal	$1,300
Laundry Systems	Internet	Alliance	Huebsch	HWFT61	No	Front-Load	Horizontal	$1,475
Mac-Gray Services	Distributor	Whirlpool	Maytag	MAH21PNAWW	No	Front-Load	Horizontal	$1,350
Texas Laundry Service	Distributor	Alliance	Speed Queen	LTS90, FTS90	No	Front-Load	Horizontal	$1,646

DOE was unable to establish either the energy or water efficiency of all the washers for which it collected retail prices. Therefore, a retail price and efficiency relationship could not be established. But based on the price data collected, it was evident that price was a function of the type of loading (*i.e.*, top-loading or front-loading.) Thus, DOE was able to determine a gross estimate of the retail price difference between a relatively inefficient top-loading washer and a high-efficiency front-loading washer. DOE also determined that price was a function of whether the washer was equipped with a coin box. As a result, DOE grouped the retail price data into four categories based on loading type and the presence of a coin box. To demonstrate the impact of the loading type and coin box on retail price, Figure 3.11.1 depicts the price data listed in Table 3.11.2. Noted in Figure 3.11.1 is the average retail price of each of the four groups into which DOE segregated the data.

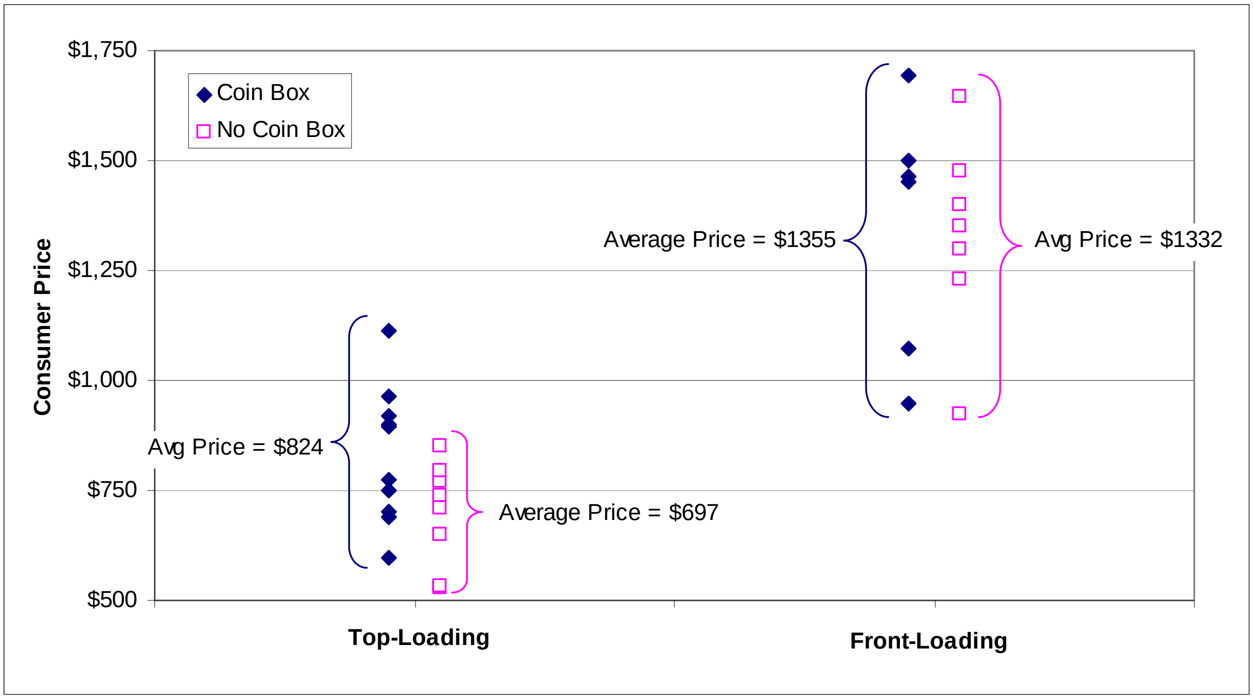

Figure 3.11.1 Commercial Clothes Washer Retail Prices as a Function of Loading-Type and Presence of Coin Box

Figure 3.11.1 demonstrates that the average price difference between top-loading and front-loading washers varies between $531 for washers with coin boxes and $625 for washers without coin boxes. The above difference provides a rough estimate of the impact on current retail pricing from moving to a conventional top-loading washer (*i.e.*, a washer with a vertical-axis agitator that submerges the clothes into a tub filled with water) to a conventional front-loading washer (*i.e.*, a washer with a horizontal axis that tumbles the clothes through a pool of water.)

As will be shown in chapter 7 of the TSD, DOE used manufacturing costs developed for specific standard levels in combination with manufacturer and distributor markups, sales taxes, and installation costs to establish the total installed cost differences between baseline and more efficient CCWs. DOE used the above range in current retail price differences between top-loading and front-loading washers as an indication of the reasonableness of the total installed cost estimates that it developed for CCWs.

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 1994-2006. 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 2006 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 [45]

Year	Production Workers ('000)	All Employees ('000)	Payroll for All Employees (2006 $ Mil)
2006	60.0	69.7	2,644.0
2005	64.3	76.9	2,778.3
2004	69.4	83.7	3,068.8
2003	71.0	85.3	3,146.5
2002	73.5	88.8	3,334.1
2001	76.6	92.6	3,497.5
2000	82.7	99.5	3,815.2
1999	82.3	97.9	3,691.2
1998	82.4	99.5	3,716.3
1997	79.8	97.2	3,547.4
1996	87.1	108.1	3,798.1
1995	88.9	110.8	3,860.6
1994	90.4	110.4	3,846.0

Table 3.12.2 presents the costs of materials and industry payroll as a percentage of value of shipments from 1994–2006. The cost of materials as a percentage of value of shipments has fluctuated slightly over the 13-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 3.12.2 Household Appliance Industry Census Data [46]

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 (%)
2006	60.9	8.9	11.5
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 3.12.3 presents the industry cost structure derived from SEC 10-K reports of publicly owned home appliance manufacturers. DOE averaged the financial data from 2002–2007 of several companies to obtain an industry average. Each financial statement entry is presented as a percentage of total revenues.

Table 3.12.3 Industry Cost Structure Using SEC Data

Financial Statement Entry	Percent of Revenues
Cost of sales	81.3%
Net income	1.7%
Selling, general and administrative	12.8%
Capital expenditure	3.3%
Research and development	2.3%
Depreciation and amortization	3.3%
Net plant, property and equipment	18.7%
Working capital	1.6%

A detailed financial analysis of each of the products covered by this rulemaking is presented in the MIA. (See chapter 13 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 shows the year-end inventory for the household appliance industry, according to the ASM. Both in dollars and as a percentage of value of shipments, the end-of-year inventory for the industry has steadily 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 [47]

Year	End-of-Year Inventory (2006 $ Mil)	End-of-Year Inventory as a Percentage of Value of Shipments (%)
2006	1,688.5	7.4
2005	1,681.3	6.6
2004	1,853.4	7.3
2003	1,857.9	7.4
2002	1,997.2	8.1
2001	2,223.1	8.8
2000	2,511.9	9.2
1999	2,503.3	9.4
1998	2,698.4	10.0
1997	2,592.9	10.0
1996	2,842.7	10.4
1995	3,139.5	11.1
1994	3,252.8	11.1

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 3.13.2 Full Production Capacity Utilization Rates[48]

Year	Rates (%)		
	Household Appliances	**Cooking Appliances**	**Household Laundry**
2006	77	65	80
2005	74	57	79
2004	76	61	77
2003	78	57	85
2002	72	56	87
2001	70	50	90
2000	70	55	88
1999	75	59	87
1998	73	66	75
1997	73	61	80
1996	76	66	81
1995	79	66	83
1994	82	72	89

3.14 TECHNOLOGY ASSESSMENT

This section provides a technology assessment for residential cooking products and CCWs. Contained in this technology assessment are details about product characteristics and operation (section 3.14.1), an examination of possible technological improvements for each product (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 each product covered by this rulemaking. These descriptions provide a basis for understanding the technologies used to improve product efficiency.

3.14.1.1 Cooking Products

Residential cooking products are appliances that enable the homeowner to heat and cook foods by means of transfer of input energy to the food load. Input energy may be electricity, gas, or a combination of the two. Cooktops consist of a horizontal surface comprising one or more heating elements. A cooking vessel is placed on the top surface of the cooktop over the element to facilitate heat transfer to the food load. In conventional and microwave ovens, the cooking vessel is placed inside a cavity within which the energy transfer takes place. Ranges incorporate both an oven and a cooktop in a single unit.

In a **gas cooktop**, pressurized natural gas or propane is supplied to each burner by means of an orifice and venturi on the underside of the cooktop surface. A sheet metal box encloses the array of burner supply lines as well as the controls for gas delivery and ignition, if provided. Primary air drawn from within the enclosure mixes with the gas at the venturis and is delivered to the ports typically arrayed radially on the burners above the cooktop surface. Gas flow and thus burner turndown is controlled by individual, typically rotary, valves connected to the burner supply lines. Upon ignition of the gas-air mixture, secondary air is entrained near the burner ports to produce a substantially radial distribution of flames. For sealed burners in which the cooktop surface interfaces directly with the base of each burner, all secondary air is introduced above the cooktop surface. Open burners can derive some secondary air from the box as well. Grates positioned above the burners allow a cooking vessel to be placed at the proper spacing to ensure adequate secondary air for complete combustion, minimization of carbon monoxide emissions, and adequate convective heat transfer for cooking efficiency.

The simplest ignition scheme for a gas cooktop utilizes a standing pilot, through which a small amount of gas is continuously supplied and burned as the ignition source for the burners. Gas cooktops equipped with electrical cords cannot have a constant burning pilot (42 U.S.C. 6295 (h)(1)) and instead utilize some form of electrically powered ignition, typically an intermittently activated spark igniter. An electronic control module may automatically energize the spark electrode whenever flame extinction is detected; otherwise the spark igniter must be manually reactivated by means of switches on the burner valve controls in the event of flame loss. Controls for the burners typically consist of manual burner adjustment as dictated by the rotary valve position. In order to achieve very low firing rates associated with such cooking processes as simmering, melting chocolate, or heating delicate sauces, some cooktops incorporate electronic controls that cycle burners on and off.

An **electric cooktop** consists of a horizontal surface with one or more electrically powered heating elements located either above or below the cooktop surface. When the elements are located above the cooktop surface, the cooking vessel is placed directly on an element to heat the vessel and contents through conductive heat transfer. The elements are resistively heated by means of the current supplied to them. An open coil-type cooktop utilizes a spiral-wound sheathed heating element. Removable drip bowls beneath each element serve as catch basins for spills. Solid disk elements contain a similar resistive element embedded in a flat, circular cast iron housing to provide a more even heating surface and greater cleanability than for a coil element. Due to this difference in cleanability, solid disk elements are classified as a separate product class from open coil elements.

Heating elements may also be located under a glass-ceramic cooktop surface. Such elements may be of a radiant, halogen, or inductive type, which will be described in more detail under the technology options in section 3.14.2.1. Each of these technologies is categorized in the smooth cooktop product class along with solid disk elements. Electronic control systems are provided to energize the desired heating elements. These controls may incorporate algorithms for modulation of the element according to cooktop and cooking process parameters.

Gas ovens are appliances designed to bake, roast, or broil foods within an insulated cavity by means of the combustion of natural gas or propane. The major components of the oven include the cavity, the gas burners, an ignition system, and a control system. If the oven incorporates a convection cooking mode, one or more fans are situated within the cavity to provide a means for forced-air distribution.

The oven cavity is a formed sheet metal enclosure with provision for holding cooking racks at varying positions. The interior surface of the cavity may be bare metal (stainless steel), or it may have a porcelain coating for durability and cleanability. Additives in the porcelain coating can provide catalytic conversion of food spilled on the surface under normal cooking temperatures, thus enabling a continuous cleaning process. Alternatively, the oven may have features that allow it to be operated under a special self-clean mode, which heats the cavity to higher temperatures than those used for cooking. In the process, food spills are pyrolized, leaving an ash residue that is easily wiped off when the cavity cools down.

Accessories such as lights and sensors for control of cooking processes are located within the cavity, while an insulated glass window in the oven door allows observation of the cooking processes without requiring the door to be opened (which would incur substantial heat loss). The outside of the cavity is wrapped with insulation to minimize heat loss to ambient surroundings. The space between the cavity and the outer sheet metal enclosure which is filled by the insulation typically is made as small as practically possible in order to maximize the cavity volume.

Gas burners are situated at the bottom of the cavity for the bake function and the top for broiling. They are typically shielded by baffles or covers to protect the burners from spills and to help distribute heat evenly. Broil elements may also be of a radiant type in which the combustion of the fuel-air mixture heats a perforated ceramic matrix or a metal mesh. As the ceramic or metal heats, it emits infrared radiation that can produce heating and surface browning of the cooking load. Combustion products from each burner and gases released during the cooking process are vented from the top of the cavity.

Ignition may be achieved through the use of a pilot or a hot surface igniter. In the case of a pilot, it may be a continuously burning standing pilot type, or an intermittently actuated spark igniter may be used to light the pilot when the oven controls are turned on. In either case, the pilot serves to heat a thermally-actuated switch that keeps the main gas valve open. With hot surface ignition, a ceramic heating element is placed in a location where the incoming gas-air mixture will impinge on it. As the element is heated electrically, its resistance goes down and current draw goes up. A bi-metallic gas valve in electrical series with the igniter deforms as its corresponding current increases, allowing gas flow as long as the hot surface igniter is energized by the burner controller.

Like gas ovens, **electric ovens** are designed to bake, roast, or broil food. The cavity is similar to those of gas ovens as well, in that the surface finishes may be bare or porcelainized, with or without the catalytic properties. In addition, electric ovens may incorporate a self-clean mode for pyrolysis of food matter on in the interior surfaces. Accessories and insulation tend to be similar between gas and electric ovens, and electric ovens also incorporate venting, although the demands of such venting are lower than those for gas ovens since there are no combustion products.

The heat source for the cooking process is typically provided by radiant elements. Bake elements are located at the bottom of the cavity, and may be either exposed or covered to provide spill protection and improve cleanability. Broil elements are situated at the top of the cavity. Far less common than radiant elements, halogen elements are also used to promote faster cooking.

An additional cooking feature on many electric ovens and certain gas ovens is convection mode, in which hot air within the cavity is circulated by means of one or more fans to speed the cooking process, promote surface crisping, and increase cooking uniformity. Supplemental heating of this recirculated air may be accomplished by means of a radiant heating element located near the fan.

Additional electrically-powered components in electric ovens may include cavity lights, electronic controls incorporating various types of displays, and cooking sensors.

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*.

3.14.1.2 Commercial Clothes Washers

Commercial clothes washers are appliances designed to clean clothes by using a solution of soap and/or detergent and water with mechanical agitation. Clothes washers use electricity to operate one or more pumps and to power an electric motor that agitates and spins the clothes. Clothes are washed, rinsed, and spun within a tub that is inside a cabinet. Because clothes washers require heated water for hot and warm water cycles, a separate water heater is typically needed to supply hot water. Most of the energy used by clothes washers is for water heating. Water is fed into the clothes washer through electrically operated water valves, one connected to a hot water supply line and a second connected to a cold water supply line.

Traditional top-loading clothes washers have an opening on the top of the cabinet, covered by a door, which gives access to the inner basket where the load to be washed is placed. The inner basket is typically perforated and is surrounded by a larger outer tub which holds the water when the machine is running. The inner basket typically contains an agitator along a vertical axis, which undergoes a reversing circular motion. The motion of the agitator, which is powered by an electric motor, circulates the clothes vertically from the bottom to the top of the basket. The spinning action of the inner basket and the drain pump are also powered by the motor. Traditional top-loading clothes washers use more water than other types of washers, and therefore, consume more energy during heated wash cycles. They also typically extract less water from laundry during the spin cycle, which results in longer drying time and greater energy consumption.

Non-agitator top-loading clothes washers may have a "wash plate" rather than an agitator to move the clothes within the basket. These top-loading clothes washers function by partially filling the tub with water for wash and rinse cycles and using very high spin speeds to extract rinse water from the clothes during the spin cycle. These top-loading clothes washers are more efficient in terms of water and energy than traditional top-loaders, but their high spin speeds that reduce drying time (and thus dryer energy consumption) may wrinkle clothing more than traditional top-loader spin speeds. These machines work best with low-foaming, high efficiency detergent.

Front-loading clothes washers utilize a cylindrical tub or drum rotating on a horizontal or nearly-horizontal axis to wash clothes. Clothes are usually loaded along the axis of the cylindrical drum, which has led to this type of clothes washer to be called a front-loader. The clothes are cleaned by tumbling them in the water (*i.e.*, clothes are lifted to the top of the drum by the rotation of the cylinder and then dropped into the water below.) The cylindrical drum is only partially filled with water for wash and rinse cycles. High spin speeds are used to extract the water from the clothes during the spin cycles. These clothes washers are typically more efficient in terms of water and energy than traditional top-loaders, but as for non-agitator top-loading clothes washers, their high spin speeds may wrinkle clothing.

Although most clothes washers using a horizontal-axis rotating drum are front-loading, they can be designed to be top-loading as well. In a top-loading horizontal-axis design, the cabinet has a door at the top that opens above the washer drum. Another door that slides or pivots open then provides access to the inner drum.

Manufacturers typically base commercial clothes washers on existing residential clothes washer platforms. This simplifies fabrication and assembly (*i.e.* commercial and residential clothes washers can be assembled on the same assembly line), and helps reduce the fixed costs associated with tooling, overhead etc. for the (typically) much lower commercial clothes washer manufacturing volumes. However, some commercial clothes washer components are selectively upgraded to make them more rugged, reliable, and vandal-resistant. Furthermore, the user interface is usually simplified (presenting the commercial user with fewer wash choices than a residential user) and the control system is designed to interface with various payment systems (ranging from coin slides to magnetic card readers). Lastly, the wash cycles may be redesigned to allow satisfactory operation in the commercial-standard 25-minute wash cycle, for example. However, some recent high-efficiency commercial clothes washer entrants feature wash cycles longer than 25 minutes, indicating that manufacturers may not be able to meet such short wash cycles in conjunction with low water and energy consumption.

3.14.2 Technology Options

In order to gain a deeper understanding of the technological improvements used to increase the efficiency of residential cooking products and CCWs, DOE identified several possible technologies and examined the most common improvements used in today’s market.

3.14.2.1 Cooking Products

DOE most recently analyzed energy conservation standards for **cooking products** in 1996 and 1997. In the 1997 analysis, DOE analyzed only gas cooking products to determine the technical and economic feasibility of eliminating standing pilots. DOE’s prior analysis in 1996, contained within the 1996 TSD for cooking products, identified technologies that have the potential for improving gas and electric cooking efficiency. DOE has considered all of these in this rulemaking. In addition, DOE identified low-standby-loss electronic controls as a technology option for several cooking products, based on review of standby power data for microwave ovens and the assumed applicability to conventional cooking products as well.

For **gas cooktops**, DOE considered the technologies listed below.

Table 3.14.1 Technology Options for Gas Cooktops

1. Catalytic burners
2. Electronic ignition
3. Insulation
4. Radiant gas burners
5. Reduced excess air at burner
6. Reflective surfaces
7. Sealed burners
8. Thermostatically controlled burners

Catalytic burners

Catalytic burners consist of a porous ceramic or refractory material such as glass or ceramic wool, impregnated with a catalyst. The gas-air mixture or gas alone is fed to the catalytic matrix, whereupon additional ambient air diffuses into it. The catalyst, typically palladium or platinum, lowers the activation energy required for combustion such that the gas-air mixture subsequently oxidizes at temperatures below those normally required for combustion. This produces a uniform, low-intensity infrared radiation with no visible flame. The burners include an electric heating element to preheat the catalyst prior to initiating operation. Catalytic burners in residential appliances are investigated primarily as a means of reducing NO_x emissions, since NO_x formation is highly temperature dependent. DOE is not aware of any commercialized catalytic burners for gas cooktops or efficiency data for applications of catalytic burners in cooking appliances.

Electronic ignition

Gas cooktops equipped without electrical power cords use a standing pilot ignition system. The energy factor of the cooktop can be increased by replacing the standing pilot system with an electronic ignition system. Actual burner efficiency is not affected by eliminating the standing pilot. The resulting increase in EF is due only to the decrease in the cooktop's annual gas energy consumption attributed to the pilot gas consumption.

The most common type of electronic ignition used by gas cooktops is an intermittent ignition system, where spark igniters replace the standing pilots. These igniters are controlled by switches on each burner valve. The switches are typically rotary-actuated so that when the burner valve is turned to the light position, a "starter" signal is sent to the control module. Alternatively, the signal can be generated by electronic controls on the user interface of the cooktop. Once the signal is received, the control module activates the spark igniters. The control module can either be a supervised or an unsupervised type. Supervised modules require re-activation of the burner switches for cases where burner flames are accidentally extinguished. Unsupervised modules use a sensor located at the burner (often the igniter itself) to sense when the flame has been accidentally extinguished. The burner switches do not need to be re-activated, as the sensor sends a signal back to the control module to reactivate the igniters. Though they cost more, unsupervised ignition systems are preferred over systems that use supervised control modules since they prevent the need to check accidentally extinguished flames. Most of the currently manufactured gas cooktops that are equipped with intermittent ignition systems use unsupervised control modules. Because of this, unsupervised control systems are the type of electronic ignition devices being analyzed for gas cooktops.

It is important to note that intermittent ignition systems consume negligible amounts of electricity. Since the control module is powered directly from line voltage, there are no 24-volt transformer losses associated with it. The spark igniter is activated for an extremely short time period so that its cumulative on-time during the course of a year, and thus its electricity consumption, is negligible.

A recently introduced igniter technology utilizes a ceramic hot surface igniter in place of the spark igniter. With this type of ignition, the igniter may either be constantly energized whenever the burner valves are open, such as on a simmer setting where the burner is cycled on and off to achieve very low average input rates, or turned on in response to either initial burner gas flow or detection of flame extinction. Therefore it may be considered an unsupervised system. Improved cooktop utility includes elimination of the noise associated with spark ignition. Energy consumption during usage is higher than for spark ignition.

Insulation

Added insulation is only used in a gas cooktop when it is installed as a countertop unit (not above an oven). Here, the surrounding structures encompassing the cooktop might experience surface temperature problems that can be alleviated by adding insulation. Insulation underneath the cooktop reduces the surface temperature of all exposed non-cooktop surfaces to levels which meet UL requirements.

Of the information reviewed on efficiency improvements to gas cooktops, adding insulation was never analyzed as a method to improve cooktop performance. Manufacturers' data from the previous rulemaking provided no estimate of energy efficiency improvements from insulating gas cooktops.

Radiant gas burners

Radiant gas burners transfer heat through infrared radiation from the burner surface. The burner consists of a porous matrix through which a premixed gas-air mixture is fed. Upon ignition, the flames sit on the surface of the matrix, heating the surface and causing it to emit radiation at infrared wavelengths. The burner is located under a glass-ceramic cooktop surface.

One form of radiant gas burners is termed the powered Infrared Jet-Impingement (IR-Jet) burner. In an IR-Jet gas burner, both radiant and convective energy are transmitted to the cooking vessel. A forced-draft combustion fan is used to deliver the fully-premixed gas-air mixture to available cooktop burners. At each burner, combustion occurs at the surface of a perforated ceramic tile. As the tile heats, it emits radiant energy, principally in the far infrared regime. Combustion products are jetted through perforations in the glass-ceramic cooktop, delivering convective energy to the cooking vessel as well.

As reported in the 1996 TSD, the Gas Research Institute (GRI) sponsored the development of the IR-Jet gas burner. With GRI's sponsorship, the American Gas Association Laboratories (AGAL) worked with a range manufacturer to produce a working IR-Jet burner. However, the IR-Jet burner is not currently being marketed. Data collected from a boiling water test indicated that the AGAL-developed IR-Jet radiant burner is more efficient than a comparable conventional open burner. The boiling water test indicated a 16-percent increase in efficiency

Another type of radiant gas burner utilizes a silicon carbide-fiber burner which emits radiation in the near-infrared spectrum. A prototype developed jointly by Tokyo Gas and Rinnai Corporation utilized such material in a glass-ceramic cooktop that did not incorporate jet impingement. Instead, combustion products were vented from underneath a solid, non-perforated cooktop. Such a radiant burner relied entirely on radiant heat transfer and conduction from the glass-ceramic after it heated up. In tests conducted according to the Japanese Industrial Standard (JIS) S 2103:1996, *Gas burning cooking appliances for domestic use*, which is a water heating procedure, the efficiency was reported as 43.5 percent compared with an estimated 30 percent for traditional gas burners.[49]

Reduced excess air at burner

The excess-air ratio is defined as the amount of air used in the combustion process of the gas burner divided by the amount of air necessary for stoichiometric combustion. Excess air is provided to ensure high-quality flame characteristics and to create a safety margin to ensure complete combustion is reached under all conditions. Reducing the excess-air ratio at the burner through redesign and shrouding can improve its efficiency. This information was provided by the 1980 engineering analysis performed by DOE[50] in support of developing energy efficiency standards for a variety of consumer products, including cooktops and ovens. This document does not specify how the burner should be redesigned and shrouded.

Reflective surfaces

Reflective surfaces for gas cooktops utilize highly polished or chromed drip pans underneath the burner. By reflecting some of the radiant heat of the burner back up to the cooking vessel, the efficiency of the burner is increased. The consumer must maintain the reflective finish by cleaning the drip pans regularly.

Efficiency gains resulting from using reflective pans are extremely small because gas flames and burners have minimal infrared emissions. The primary mechanism for heat transfer to the cooking vessel is convection. The efficiency increase was obtained from using manufacturers' data provided by AHAM and reported in the 1996 TSD. The data indicate that an efficiency increase of only 0.1 percent is realized due to the incorporation of reflective surfaces.

Sealed burners

Unlike conventional (open) burners, the cooktop surface surrounding sealed burners interfaces directly with the base of the burner. This results in a reduced amount of secondary air to the burner for combustion. According to the 1996 TSD, AHAM stated that sealed burners often have a lower gas input rating than conventional burners due to the reduction in secondary air. The sealed burner must obtain all of its secondary air from above the cooktop. In order to obtain sufficient air for proper combustion, it becomes necessary to either raise the grate height or de-rate the burner. Contrary to these statements, a report from the 1983 International Gas Research Conference[51] states that the reduction in secondary air results in more primary aeration to the sealed burner. The increased primary aeration allows for a reduced pan-to-burner separation and increased burner efficiency. According to the boiling water tests conducted in the report, the efficiency of conventional burners ranged from 42–48 percent, while the sealed burner was rated at an efficiency of 53 percent.

Manufacturers' data provided by AHAM were used to estimate the increase in efficiency due to sealed burners in the 1996 TSD. An efficiency increase of approximately 2.0 percent was estimated.

Thermostatically controlled burners

Thermostatically controlled gas burners control the gas flow to the burner through the use of a sensing element that extends through an opening in the center of the burner. This sensing element makes contact with the bottom of the cooking vessel, detecting the temperature and controlling the input rate to the burner accordingly. If the cooking vessel has an uneven bottom in the area where the sensor is supposed to make contact, however, any type of useful temperature control is lost.

Thermostatically controlled burners were widely sold in the late 1950s and 1960s. But due to customer complaints on the operating characteristics of the burner, manufacturers dropped this feature. As reported in the 1996 TSD, manufacturers stated that the sensor's electric element retains heat due to its mass. This results in the sensor being "fooled" and causing delays in reaction time. These delays allow wide swings in the thermostatically controlled temperature. Manufacturers stated that even if improvements in sensor manufacturing resulted in no heat retention, the many existing variables associated with the cooking vessel (*e.g.*, vessel material, food mass, type of food) make the thermostatically controlled burners' utility and energy efficiency suspect.

For **open (coil) element electric cooktops**, DOE considered the technologies listed below.

Table 3.14.2 Technology Options for Open (Coil) Element Electric Cooktops

1. Electronic controls
2. Improved contact conductance
3. Insulation
4. Low-standby-loss electronic controls
5. Reflective surfaces

Electronic controls

Electronic controls using sophisticated control algorithms can use the dynamic thermal properties of the element to turn off the energy input to the element just in time to "coast" to the desired final temperature without overshooting it.

Research has been conducted to determine the effect that electronic controls have on cooktop efficiency. Danish researchers, testing breadboard versions of microprocessor-controlled electric hotplates, found a 20- to 46-percent energy savings in cooking a variety of foods with European recipes.[52]

Improved contact conductance

The thermal contact resistance that arises from an imperfect contact between the cooking vessel and the open (coil) element can be reduced by improving the flatness of the element. An improved contact conductance allows for more heat to be transferred to the cooking vessel and, thus, an improvement in the efficiency of the element.

As stated in the 1996 TSD, manufacturers asserted that they have worked on improving the flatness of the element and that the types that are available currently are doing an excellent job. They also stated that the results obtained from DOE test measurements do not reflect the actual performance of the open element. The aluminum test block used in the test procedure is much flatter than actual cooking vessels. Because of the block's very flat surface, test efficiencies will be higher than those obtained from field measurements using "real" cooking vessels. Therefore, according to the manufacturers, increases in efficiency that can be obtained by improving the contact conductance under DOE test conditions will not be realized under field conditions.

Sources used in assessing the efficiency gains that could be expected from improving the contact conductance in the 1996 analysis included: (1) manufacturers' data provided by AHAM; (2) a costing analysis of technology options for residential appliances prepared by ADM Associates for Lawrence Berkeley National Laboratory (LBNL);[53] and (3) an energy efficient electrical product knowledge base prepared by ORTECH International for the Canadian Electrical Association.[54] An additional comment[55] received from Arthur D. Little, Inc. (ADL) following the NOPR for the previous rulemaking reported that the major mechanism for heat transfer was physical contact between the vessel and coil, not contact pressure. Averaging the data from these sources results in a relative efficiency increase for this technology option of just over 3 percent.

Insulation

Added insulation is only used in an open (coil) element electric cooktop when it is installed as a countertop unit (not above an oven.) Here, the surrounding structures encompassing the cooktop might experience surface temperature problems that can be alleviated by adding insulation. Insulation underneath the cooktop reduces the surface temperature of all exposed non-cooktop surfaces to levels which meet UL requirements.

Of the published information reviewed on efficiency improvements to open (coil) element electric cooktops, adding insulation was never mentioned as a method to improve cooktop performance. Manufacturers' data provided no estimate of efficiency improvements from insulating cooktops.

Low-standby-loss electronic controls

Electronic controls may consume power even when the electric cooktop is not performing its intended function. Depending on the implementation of the controller, standby power is required to enable the electronic controls to detect user input without the user first having to turn on a mechanical power switch or to enable displays, illuminate switches, etc. Reducing the standby power consumption of electronic controls would reduce the annual energy consumption of the electric cooktop, but would not impact the energy consumption of the electric cooktop during operation.

Reflective surfaces

As described in the similar technology option for gas cooktops, this technology option utilizes highly polished or chromed drip pans underneath the heating element. By reflecting some of the radiant heat of the element back up to the cooking vessel, the efficiency of the element is increased. The consumer must maintain the reflective finish by cleaning the drip pans regularly.

Efficiency gains resulting from using reflective pans are extremely small. The efficiency increase assumed in the 1996 TSD was obtained from data from the following sources: (1) manufacturers' data provided by AHAM; (2) the energy efficient electrical product knowledge base prepared by ORTECH International for the Canadian Electrical Association;[56] and (3) the 1980 DOE engineering analysis for residential appliances.[57] Averaging the data from these sources results in an efficiency increase of 1 percent.

For **smooth element electric cooktops**, DOE considered the technologies listed below. Radiant elements, which were included in the 1996 TSD, were not considered as a design option for this rulemaking because manufacturer data provided to DOE for the 1996 TSD indicated that this technology does not offer an efficiency improvement over the baseline according to the DOE test procedure.

Table 3.14.3 Technology Options for Smooth Element Electric Cooktops

1. Electronic controls
2. Halogen elements
3. Induction elements
4. Low-standby-loss electronic controls

Electronic controls

Sophisticated electronic controls can be applied to solid disk elements, radiant elements, and halogen elements to allow the element to "coast" to its final temperature. Electronic controls are not applicable to induction elements as the nature of its operation has no need for "coasting" controls. DOE is unaware of any efficiency data characterizing energy savings for electronic controls on smooth element cooktops. However, research previously cited suggests potential energy savings of this technology for open (coil) element cooktops and it is possible that similar energy savings could be achieved for smooth element cooktops.

Halogen elements

Halogen elements transfer energy to the cooking vessel by direct infrared radiation from high-powered tungsten-halogen lamps. The halogen element lies underneath a glass-ceramic panel and consists of one or more lamps installed horizontally within a corrosion-protected metal dish. The bottom of the metal dish is insulated with microtherm insulation.

Radiant heating coils are commonly fitted around the halogen element to provide heat around the element's edge. This results in a highly responsive element that provides an even temperature distribution. Halogen elements can be configured to operate across a wide range of capacities. Parallel or series lamp arrangements can yield power outputs from 1200–2500 W. Halogen lamp technology reported in the 1996 TSD consisted of a circular lamp that can provide a more optimum temperature distribution than traditional straight lamps. This circular lamp has the trademark name of Haloring.

The 1996 TSD reported that with the continued development of halogen elements, efficiencies had increased. The circular halogen-lamp elements that had recently been developed at the time of the previous analysis could exceed the efficiency of solid disk elements as measured according to the DOE test procedure. Data provided for the 1996 rulemaking by a cooktop manufacturer were used to establish the efficiency gain of a circular halogen lamp element over that of a solid disk element. An efficiency increase of approximately 1.5 percent was measured. It is important to reiterate that this efficiency increase was only for the circular halogen lamp element. Other halogen lamp elements might not yield the same efficiency increase. The same cooktop manufacturer mentioned above also provided efficiency data based on boiling water tests. These tests indicated that circular halogen lamp elements can yield even higher efficiency increases over that of solid disk elements. European manufacturers had also conducted boiling water tests indicating that halogen lamp elements (the configuration of halogen lamp tested was not specified) are more efficient than solid disk elements.[58]

Induction elements

Induction elements use a solid-state power supply to convert 60 hertz alternating line current into a high-frequency (approximately 25 kilohertz) alternating current. This high-frequency current is supplied to an inductor. The inductor is a flat spiral winding located just underneath a glass-ceramic panel. The high-frequency current, which is supplied to the inductor, causes it to generate a magnetic field which passes through the glass-ceramic panel unaffected and produces eddy currents in the bottom of the cooking vessel. The vessel must be made of ferromagnetic material, and the eddy currents that are generated within it cause it to heat up. Thus, the vessel essentially becomes the heating element.

A sensor is placed between the inductor and the glass-ceramic panel, providing a continuous temperature measurement of the vessel bottom. Sensors also enable the inductor to only heat objects of at least 4 inches in diameter. This prevents any small metal objects, such as forks or spoons, from accidentally being heated. In addition, since the glass-ceramic panel is unaffected by the magnetic field, it remains relatively cool, reducing the potential for accidental burns.

The primary advantages of induction elements are their fast response and control of the heat source, their ease of cleaning, and their ability to heat vessels that are not flat. Because these features have usually been associated with gas burners, induction elements are being marketed in competition to them.

As just noted, the cooking vessel used with an induction element must be made from a ferromagnetic material. Since aluminum is not a ferromagnetic material, the current DOE test procedure, which specifies an aluminum test block, cannot be used to rate this equipment. In 1978, the National Bureau of Standards (NBS), now called National Institute of Standards and Technology (NIST), developed a proposed method of measuring the energy consumption of induction cooktops.[59] The method is a modification of the current DOE test procedure. Energy use is determined by attaching a ferromagnetic material to the bottom of the aluminum test block. This modification was never formally adopted by DOE, but a source was found that provided data on how a typical induction element performed under the proposed method developed by NBS.[60] An absolute efficiency of 84 percent was presented.

Low-standby-loss electronic controls

Electronic controls may consume power even when the electric cooktop is not performing its intended function. Depending on the implementation of the controller, standby power is required to enable the electronic controls to detect user input without the user first having to turn on a mechanical power switch or to enable displays, illuminate switches, etc. Reducing the standby power consumption of electronic controls would reduce the annual energy consumption of the electric cooktop, but would not impact the energy consumption of the electric cooktop during operation.

For **gas and electric ovens**, DOE considered the technologies listed below.

Table 3.14.4 Technology Options for Gas and Electric Ovens

1. Bi-radiant oven (electric only)
2. Forced convection
3. Halogen lamp oven (electric only)
4. Improved and added insulation
5. Improved door seals
6. Low-standby-loss electronic controls
7. No oven-door window
8. Oven separator
9. Pilotless ignition (gas only)
10. Radiant burner (gas only)
11. Reduced conduction losses
12. Reduced thermal mass
13. Reduced vent rate
14. Reflective surfaces
15. Steam cooking

Bi-radiant oven (electric only)

A bi-radiant electric oven system was developed by Purdue University for Oak Ridge National Laboratory in the late 1970s.[61] The objective of the project was to develop an electric oven that offered significant energy savings without compromising food quality. The bi-radiant oven has three important features which provide improved performance: (1) the cavity walls are highly reflective rather than absorptive, thereby allowing these surfaces to operate at cooler temperatures; (2) the heating elements, similar in construction to those in conventional ovens but operating at much lower temperatures, provide a prescribed, balanced radiant flux to the top and bottom surfaces of the food product; and (3) the baking and roasting utensils have a highly absorptive finish.

The bi-radiant oven was tested under a variety of cooking conditions (including the DOE test procedure) and also modeled (using computer thermal analysis programs) to determine its performance. It demonstrated a greater than 50-percent increase in efficiency over that of a conventional oven. In addition, the separate upper and lower heating elements required by the oven provided more flexibility in baking and roasting.

Several important practical concerns have to be addressed by manufacturers in order to realize the demonstrated energy savings: (1) the oven lining material must be durable enough to maintain the low-emissivity (less than 0.1) cavity surface; (2) microprocessor controls must be used; and (3) as mentioned earlier, the baking and roasting utensils must have a highly absorptive exterior. However, given the assumption that all of these criteria are met, the 1996 analysis assumed a 50-percent efficiency increase.

Forced convection

A forced convection oven uses a fan to distribute warm air evenly throughout the oven cavity. The use of forced circulation can reduce fuel consumption by cooking food more quickly, at lower temperatures, and in larger quantities than a natural convection oven of the same size and rating. The fan is placed within the rear cabinet wall and a protective screen is placed around it. The screen prevents any items being placed in the oven from "knocking" into the fan and causing damage. The screen may also assist in distributing the heated air evenly throughout the cavity. Product literature from manufacturers indicates that cooking times can be reduced by using forced convection cooking.[62] As a result, forced convection is widely used in electric ovens.

For gas ovens, GRI sponsored the development of two new types of ovens that incorporate forced convection cooking. Both oven types, one an advanced countertop oven and the other an advanced full-size oven with pyrolytic self-cleaning, also have steam-cooking options. Research and development of the ovens was being conducted at ADL at the time of the 1996 TSD. Of the two oven types, development of the countertop oven was farther along. Test results indicated that countertop oven cooking times are as fast as those found in microwave ovens.[63] More recently, multiple manufacturers have introduced gas ovens with convection fans.

Estimates from manufacturers, researchers, and published reports (*e.g.*, the energy efficient electrical product knowledge base prepared by ORTECH International for the Canadian Electrical Association[64]) were included in the 1996 TSD analysis to establish the efficiency increase due to forced convection. Averaging these estimates results in a relative efficiency increase of 23 percent for gas self-cleaning ovens using forced convection cooking. For gas standard ovens a value of 4.8 percent was used based on more recent GRI data.[65] Additional data submitted during the NOPR comment period of the 1996 analysis by ADL[66] showed an increase in efficiency for electric convection ovens of only 2.4 percent. .

It is also important to consider the added electrical energy consumption of the convection fan when determining the EF for ovens incorporating convection cooking. The wattage of a typical convection fan motor is approximately 30 W. Since the duration of the DOE test procedure is approximately 30 minutes, the energy consumption of the convection fan is approximately 15 watt-hours (Wh).

Additionally, ovens can use convection elements in addition to resistance and other types of elements to speed up the cooking process. By utilizing different cooking elements where they are most effective, such combination ovens can reduce the time and energy consumption required to cook food. For example, a convection heater and resistance element can provide rapid internal heating while a halogen element provides surface heating and browning. GE has introduced a line of combination ovens utilizing conventional resistance heating elements, convection heaters, and halogen elements, along with a microwave system.[67] GE claims that this technology can reduce food preparation times by 50 percent to over 75 percent, depending on the item being cooked.[68] However, it is unclear how much of the benefit is attributable to the forced convection system alone.

Halogen lamp oven (electric only)

Halogen elements, similar to those used in electric cooktops, can also be used in electric ovens. This oven type was first introduced in Europe, but according to U.S. manufacturers, its acceptance has been slow in the United States. Manufacturers stated in 1996 that the cooking performance of the halogen lamp oven is relatively poor compared to that of a conventional oven, though it might be advantageous for certain broiling applications.

Alternatively, a conventional oven can use halogen elements in addition to resistance and/or convection elements to speed up the cooking process. By utilizing different cooking elements when they are most effective, combination ovens such as the GE product described previously for the forced convection technology option can reduce the time and energy consumption required to cook food. However, no data were found or submitted to demonstrate how efficiently halogen elements alone perform relative to conventional ovens.

Improved and added insulation

The efficiency of an oven can be increased by either improving the insulation or adding more insulation to the cabinet walls and oven door. Most models can accommodate 4 inches of insulation in the cabinet walls and door without requiring extensive design changes to the oven. Most standard models have 2 inches of low-density (1.09 pounds (lb)/ft^3) fiberglass insulation in the cabinet walls and door, while most self-cleaning ovens use 2 inches of high-density (1.90 lb/ft^3) insulation. Insulation is added primarily to pass UL surface temperature tests, which explains why self-cleaning ovens, which require high temperatures for pyrolysis, tend to have a more effective insulation package.

Data found in published papers and reports indicate that fiberglass insulation density levels do not exceed those found in self-cleaning ovens (1.90 lb/ft^3). Thus, while both the thickness and density of the insulation can be increased in most standard ovens, only the thickness can be increased in most self-cleaning ovens.

Since the DOE test procedure does not require maintaining heat in the oven over an extended period of time, manufacturers stated in the 1996 rulemaking that increasing the thickness or density of the oven's insulation will demonstrate no energy savings. But data provided by several sources indicate that small energy savings can be realized under the conditions of the DOE test procedure.

The following sources were used in the 1996 TSD to establish the efficiency increase from using a denser insulation (1.09 to 1.90 lb/ft^3): (1) manufacturers' data provided by AHAM; (2) the costing analysis of design options for residential appliances prepared by ADM Associates for LBNL;[69] (3) the energy efficient electrical product knowledge base prepared by ORTECH

International for the Canadian Electrical Association;[70] and (4) the 1980 DOE engineering analysis for residential appliances.[71] Averaging the data from these sources results in an efficiency increase of 4.9 percent for standard gas ovens and 5.2 percent for standard electric ovens.

Two sources of data were available which showed an increase in efficiency due to adding more insulation (2 to 4 inches): (1) manufacturers' data provided by AHAM for the 1996 TSD and (2) the 1980 DOE engineering analysis for residential appliances.[72] Averaging these data points results in an efficiency increase of approximately 1.4 percentage points. However, GRI reported no change in energy consumption by adding insulation.[73]

Improved door seals

Door seals for standard ovens generally consist of a strip of silicone rubber, while self-cleaning ovens usually incorporate fiberglass seals. These seals are attached to the oven front frame and act as a seal for the door, which serves to reduce the loss of hot oven air through the door. Because some venting is required for proper cooking performance, a complete seal on the oven is undesirable. But the oven door seals can be improved further without sealing the oven completely.

Data from the energy efficient electrical product knowledge base prepared by ORTECH International for the Canadian Electrical Association[74] were used to estimate the efficiency increase from improving the door seals. The data indicated that an approximately 7-percent increase in efficiency was possible for standard electric ovens and both standard and self-cleaning gas ovens. However, more recent data by GRI[75] show efficiency increases much less than the 7-percent value previously reported. A value of 1 percent, therefore, was used for the standard and self-cleaning gas oven analysis. The GRI report also pointed out the need for sufficient air flow though the oven cavity for proper heating and moisture conditions while cooking.

Low-standby-loss electronic controls

Electronic controls may consume power even when the oven is not performing its intended function. Depending on the implementation of the controller, standby power is required to enable the electronic controls to detect user input without the user first having to turn on a mechanical power switch or to enable displays, illuminate switches, etc. Since clock power is incorporated into the EF metric for both gas and electric ovens, reducing the standby power consumption of electronic controls would reduce the EF. Low-standby-loss electronic controls can be implemented in a wide variety of ways.

No oven-door window

Most ovens and ranges come equipped with windows in the door. Using the window, the contents of the oven can be viewed without opening the oven door. But oven-door windows allow more energy to be lost through the door and, thus, reduce the efficiency of the oven. It could be argued, however, that having no window in the door necessitates frequent door openings to check the contents of the oven. The lost energy caused by these door openings could offset any energy savings that would result from eliminating the door window.

GRI issued a topical report[76] which discussed this technology option. The report was submitted as a written comment to the 1996 NOPR. GRI's experimental tests showed a small savings in annual energy usage for both standard and self-clean ovens. However, they reported there could actually be a net energy loss due to consumer practices, which would be a function of the number of times a consumer would open the door to inspect the food while cooking. With four door openings per test according to the DOE test procedure, a standard oven would realize a net energy savings of 34 kBtu/yr. For a self-clean oven, however, GRI calculated a net energy loss of 3 kBtu/yr.

Oven separator

For loads that do not require the entire oven volume, an oven separator can be used to reduce the cavity volume that is used for cooking. With less oven volume to heat, the energy used to cook an item would be reduced. The oven separator considered here is the type that can be easily and quickly installed by the user. The side walls of the oven cavity would be fitted with "slots" that guide and hold the separator into position. Different pairs of "slots" would be spaced throughout the oven cavity so that the user could select different positions to place the separator.

Manufacturers' data provided by AHAM indicated that an absolute percentage point increase of approximately 0.82 is expected from using an oven separator in standard and self-cleaning electric ovens. For standard and self-cleaning gas ovens, percentage point increases of 0.1 and 0.53 are expected, respectively. No other data were provided to demonstrate whether the efficiency increase should be any higher or lower.

As of June, 2008, oven separators have been researched but never been put into production.

Pilotless ignition (gas only)

Gas ovens equipped without an electrical power cord use a standing pilot ignition system. The EF of the oven can be increased by replacing the standing pilot system with an electric or electronic ignition system. Actual oven cooking efficiency is only slightly affected by eliminating the standing pilot. The resulting increase in the EF is primarily due to the decrease in the oven's gas energy consumption during standby.

For gas ovens equipped with a power cord, there are two types of pilotless ignition systems: (1) a spark ignition system and (2) a "glo" ignition system. The spark ignition system uses a spark igniter to light a pilot. The pilot in turn ignites the oven burner. The igniter is controlled by a control module, which is activated when the thermostat knob is set to a specific temperature. The igniter will spark until the pilot is ignited, and the pilot will burn until the thermostat is turned off. If the pilot should accidentally be extinguished, a sensing circuit within the igniter will reactivate the control module and cause the igniter to spark. The spark ignition system consumes a negligible amount of electricity. Since the control module is powered directly from line voltage, there are no 24-volt transformer losses associated with it. The spark igniter is activated for an extremely short time so that its cumulative on-time during the course of a year, and thus its annual electricity consumption, is negligible.

The "glo" ignition system uses a ceramic "glo"-type igniter. When the thermostat is set to a specific temperature, line voltage is applied to the igniter. Once energized, the igniter draws typically slightly over three amps and heats to a high temperature. In series with the igniter is a safety valve that is electrically activated. Once the igniter current drops to a pre-determined amperage, the safety valve opens, allowing gas to flow to the oven burner. The hot "glo" igniter then ignites the oven burner. Because the safety valve remains open only when the "glo" igniter is drawing the correct current, the igniter must continually draw power (typically around 400 W) to keep the burner ignited.[77] Thus the electrical energy consumption of a "glo" ignition system is significant. There are other types of igniters which draw less wattage which are called "mini" hot surface igniters (HSI). Typical mini-HSIs draw about 50 W and one is reported to operate at 24 W. However, these low-wattage igniters draw less current than standard "glo" igniters, and therefore are below the threshold current needed to open the safety valve. A change in design of the control systems would be required to incorporate these mini-HSIs into cooking oven products.

Radiant burner (gas only)

Viking manufactures a gas oven with a radiant burner for broiling functions. The infrared element is a metal screen heated by a burner until it emits infrared radiation, rapidly heating food and searing the outside, while the conventional heat from the flame provides additional food heating.

Reduced conduction losses

Conduction losses from the oven can be reduced by upgrading the oven door. This upgrade includes an additional thermal break and a modified inner panel. In the 1996 rulemaking, manufacturers stated that with existing instrumentation, the DOE test procedure cannot measure the small energy gains that can be obtained by attempting to reduce conduction losses.

However, manufacturers' data provided by AHAM for the 1996 TSD indicated that a very small efficiency increase is possible. The data indicate that only an absolute percentage point increase of 0.05 is expected from reducing conduction losses. No other data were obtained to demonstrate whether the efficiency increase should be any higher or lower.

Reduced thermal mass

Energy is absorbed by the oven components as the oven warms to its operating temperature. By reducing the amount of material used in constructing the oven, the amount of energy that is absorbed is reduced and hence the efficiency increases. One method of achieving this thermal mass reduction is to reduce the gauge of sheet metal used in constructing the oven. Manufacturers asserted that this type of thermal mass reduction was not possible without compromising structural integrity (during both use and transportation) and increasing heat losses for electric and gas ovens manufactured at the time of the 1996 TSD. Manufacturers stated that the oven walls must provide strong enough support to hold racks when baking heavy items (*i.e.*, turkeys or large roasts) and that oven cavity metal thickness could not be reduced any further without risking cracking and greater heat losses.

Several sources of data for the 1996 TSD indicated that a 10–20 percent reduction in thermal mass is possible. The sources, which state that an efficiency increase from reducing the thermal mass is possible, included the following: (1) manufacturers' data provided by AHAM; (2) the costing analysis of design options for residential appliances prepared by ADM Associates for LBNL;[78] and (3) the energy efficient electrical product knowledge base prepared by ORTECH International for the Canadian Electrical Association.[79] GRI tests showed only a 0.58-percent efficiency improvement for a self-cleaning oven with an equivalent of 5.52 pounds of wall material removed.[80]

Reduced vent rate

Oven vents function primarily to remove the moisture present during the baking process. Self-cleaning ovens have reduced vent diameters to limit the air flow in accordance with combustion safety regulations during the high-temperature cleaning cycle. For safety reasons for the combustion process, the vent rate found in self-cleaning ovens cannot be reduced any further. But the vent rate of standard ovens can be reduced to the vent rate of self-cleaning ovens. This can be accomplished by either reducing the vent-tube size or adding a baffle. A reduction in vent rate causes a corresponding increase in efficiency.

Manufacturers stated in the 1996 TSD that reduced vent rates should only be considered for standard electric ovens. The vent diameters of standard and self-cleaning gas ovens are not significantly different, since both oven types need to maintain a satisfactory combustion environment. With regard to standard electric ovens, manufacturers asserted that vent sizes are unique to the design of the oven. The vent size is critical in maintaining the oven's proper cooking and safety performance. According to the manufacturers, mandating a specific vent rate would require most oven models to be redesigned in order to maintain their proper performance.

But manufacturers' data provided by AHAM for the 1996 TSD indicated that the vent size of both standard electric and standard gas ovens could be reduced. Since all self-cleaning ovens are already designed with this technology, no new improvements are required by the industry to incorporate this technology option. Averaging the manufacturers' data with data obtained from the costing analysis of design options for residential appliances prepared by ADM Associates for LBNL[81] results in an increase of approximately 0.62 absolute percentage points for standard electric ovens and 0.5 absolute percentage points for standard gas ovens.

Reflective surfaces

Oven efficiency can be improved by incorporating reflective surfaces onto the walls of the oven cavity. Reflective surfaces improve the oven's performance by reflecting and retaining infrared radiation within the oven cavity, thus increasing the percentage of heat available to be transferred to the food load.

GRI performed tests on this technology option which resulted in a decrease in energy efficiency.[82] The reflective surface interfered with the convective currents and the thermostat, thus fooling the thermostat into cycling. GRI reported that increased reflectance from the chrome-plated inner surface of the oven caused repeated thermostat cycling that "might have contributed to the higher energy consumption," which resulted in a 12.61-percent decrease in energy efficiency. ADL also commented that the reflected radiation is different from the normal radiation emitted by the oven cavities currently in use.[83]

Based on these studies, it is uncertain whether, or how much, energy savings are realizable with this technology option. A smarter controller for the oven seems to be a reasonable fix for the thermostat cycling problem. However, there is a general lack of sophistication in the technology to maintain clean, reflective surfaces over the lifetime of the product. Manufacturers stated in the previous rulemaking that reflective surfaces degrade throughout the life of the oven, particularly for self-cleaning ovens.

Steam cooking

With steam cooking, energy is transferred to the food load by means of the condensation of steam on the food surface. This may take place at essentially atmospheric pressure, or the cavity may be pressurized in order to allow higher steam temperatures and thus higher energy transfer to the food. In order to maintain the proper environment regardless of pressure, a "steam-tight" oven cavity must be maintained. In addition, the use of steam involves considerably higher demands on the oven's design and materials. Not only are different cavity materials required (*e.g.*, temperature-resistant silicone seals and chrome-nickel steel), but all incorporated elements and accessories have to be redesigned and intensively tested. Though incorporating steam cooking into oven designs is a difficult task, various manufacturers claim that there are advantages to using steam over conventional methods of cooking. Those advantages include saved energy and being able to retain more of the food's nutritional value. Energy is saved because food items that normally would need to be cooked separately (*e.g.*, a meat roast in an oven and vegetables on a cooktop) can be cooked together using the steam cooking process.

There are several electric ovens with steam functions currently on the market. BSH Home Appliances has recently introduced the Gaggenau Combination Steam and Convection Oven. The oven utilizes a steam injection valve to control steam delivery to the cavity. The temperature and humidity level in the oven are user-selectable to tailor the cooking process as needed. Speed cooking is not advertised as the primary feature of this oven. Rather, food quality and nutrition is the focus. The steam capability is described as allowing vegetables to be cooked while retaining texture and nutritional content, meat to be roasted without drying out, and leftovers to be reheated without the loss of flavor and texture often associated with microwave reheating.[84] Since this is a built-in oven, water delivery and condensate drainage are provided via plumbing lines much like a dishwasher. Along with Miele and Viking, Gaggenau also markets a steam convection oven which does not require any external plumbing. Instead, it utilizes a refillable container for water supply and collection.

While speed cooking is not the primary focus of steam ovens, there is evidence that there is time savings, particularly with larger food loads. Sharp's countertop Superheated Steam Oven, introduced in August 2004[85] and which incorporates steam generators with conventional resistive heating elements, is described as reducing cook times for items such as chicken by 50 percent.[86]

DOE is unaware of any efficiency data for steam ovens.

For **microwave ovens**, in the 1996 TSD, DOE considered all of the following technologies to improve EF, with the exception of cooking sensors, dual magnetrons, and low-standby-loss electronic controls. DOE identified cooking sensors from product literature, while dual magnetrons were identified in the February 2006 edition of *Appliance Design* as a means to decrease cooking times. Low-standby-loss electronic controls were identified by a review of AHAM data for standby power.

Table 3.14.5 Technology Options for Microwave Ovens – Energy Factor

1. Added insulation
2. Cooking sensors
3. Dual magnetrons
4. Eliminate or improve ceramic stirrer cover
5. Improved fan efficiency
6. Improved magnetron efficiency
7. Improved power supply efficiency
8. Low-standby-loss electronic controls
9. Modified wave guide
10. Reflective surfaces

Added insulation

Adding insulation to the outside of the reflective cavity wall of the oven would diminish heat flow through the walls. However, because the walls absorb a negligible fraction of the microwave energy, there is very little difference in temperature between the inside and the outside of the microwave oven. Also, during the short duration of the DOE test procedure, the microwave oven cavity walls do not heat up. Thus, the energy savings of this technology option would be so small as to be not measurable.[87]

Cooking sensors

Moisture or humidity sensors can be incorporated into the microwave oven to detect the cooking state of the food load during operation, inferred by the water vapor being released into the cavity. When the sensor detects that a desired cooking state has been reached, the controller shuts off the microwave oven, thereby preventing excess energy consumption in addition to optimizing food quality. However, DOE is unable to obtain any data to verify any energy efficiency impacts.

Dual magnetrons

Dual-magnetron microwave ovens use two magnetrons to distribute microwave energy within the cavity in order to more evenly heat food. Conventional microwave ovens use a single magnetron to generate microwaves, and may use a stirrer to distribute these microwaves within the microwave cabinet. In addition, most microwave ovens use a turntable to rotate the item being heated in order to increase food heating uniformity. In order to vary the power of the microwave, the duty cycle of the magnetron is varied.

When food is heated unevenly in a microwave, consumers must microwave items longer than necessary to ensure the entire item reaches the desired temperature. When a microwave oven uses dual magnetrons to more evenly distribute microwaves, this additional heating to ensure high temperature throughout the food may be reduced, reducing microwave energy consumption.

In addition to increasing warming uniformity, dual magnetrons may reduce the need to cycle the single magnetron in most residential microwave ovens in order to modulate power. Cycling the single magnetron may increase wear on the magnetron, reducing its efficiency over its lifetime. Using two small magnetrons which together match the power of a single larger magnetron allows only one of these magnetrons to be engaged when then microwave oven is operated at reduced power levels. However, if both magnetrons share a single high voltage transformer, the decreased transformer efficiency at partial loading may offset any magnetron efficiency gains from replacing a single cycled magnetron with dual magnetrons. DOE is unaware of any energy efficiency data on dual magnetrons.

Eliminate or improve ceramic stirrer cover

Microwave ovens with fan-type mode stirrers use a cover over the fan to prevent inadvertent damage to the fan when inserting or removing food and to prevent degradation of the wave guide due to food splatter. Such models (with browning elements) sometimes use a ceramic mode stirrer cover because plastic types may not withstand the heat generated by the heating element during the browning operation.[88] These stirrers absorb some microwave energy but are needed to prevent food splatter inside the wave guide. Eliminating the ceramic cover would adversely affect consumer utility by requiring cleaning of the stirrer or by reducing the life of the stirrer.

Improved fan efficiency

Microwave ovens use either one or two fans. One fan is used to remove heat generated by the magnetron from the cavity. The second fan would be used where mode stirring is accomplished by using slow-moving metal blades. This allows for better distribution of the microwave energy. Since power demand is very low (2–3 W), there is no opportunity for energy savings in models equipped with a second fan. The blower fan that is used to cool the magnetron and other electrical components uses about 25 W. Increasing the efficiency of this fan can reduce microwave oven energy consumption. Additional data submitted during the NOPR comment period of the previous rulemaking were incorporated into the 1996 analysis. According to these data, the expected energy savings would be less than originally reported and would have increased cost. These data were averaged with the original data and included in the previous analysis. The increase in efficiency is estimated to be 0.23 absolute percentage points.

Improved magnetron efficiency

Magnetrons convert electrical energy input into electromagnetic energy at microwave frequency. The conversion efficiency of a magnetron, also known as the oscillation efficiency, is expressed as output power divided by the power delivered to the anode. In the range of output powers typical of residential-scale microwave ovens (700–1300 W), nominal magnetron efficiency is approximately 73 percent.[89] Technologies are being investigated by manufacturers to increase efficiencies by several percentage points. Strategies to boost efficiency include improving the permanent magnet to reduce its demagnetization over time and reducing the magnetron dark current. Oscillation efficiencies of up to 78 percent have been reported.[90]

Improved power supply efficiency

In order to operate a magnetron, a transformer must be used to increase the input line voltage from 120 volts to about 4,000 volts. A controller, which may dissipate as much as 30 W, controls the power supply. There are two types of high voltage power supplies that are used in microwave ovens. The predominant type is the inductive-capacitance transformer, known as the LC power supply, which has an efficiency of about 82 percent. The other type is the inverter-type, which is more expensive but has an efficiency of about 84 percent.[91] An improved power supply can be obtained through reduced losses in the controller and in the iron core of the transformer. An efficiency as high as 96 percent is theoretically possible,[92] but does not appear practicable at reasonable cost. Higher efficiency general purpose transformers do not have stable enough output power for microwave oven application. Earlier estimates of efficiency increase were 7 percent. However, data supplied by Sharp showed this estimate is much too high.[93] The value used for the current analysis is a 2.9-percent increase in power supply efficiency.

Low-standby-loss electronic controls

Electronic controls may consume power even when the microwave oven is not performing its intended function. Depending on the implementation of the controller, standby power is required to enable the electronic controls to detect user input without the user first having to turn on a mechanical power switch or to enable displays, illuminate switches, etc. Reducing the standby power consumption of electronic controls would reduce the annual energy consumption of the microwave oven, but would not impact the energy consumption of the microwave oven during cooking operation. DOE is unaware of any standby power data to quantify the impact on energy savings.

Modified wave guide

Wave guides provide the interface between the microwave oven cavity and the magnetron. They have very high efficiencies in current models of microwave ovens. A small improvement (about 1 percent) is possible through the use of special coatings on the interior surface.[94] According to AHAM, the losses associated with the wave guide are typically less than 0.5 percent of the overall energy consumption.[95]

Reflective surfaces

Microwave ovens are designed to have surfaces that are highly reflective of microwave energy. A high-grade stainless steel cavity would be more reflective than a painted or porcelainized cavity interior. Testing by manufacturers has shown that high-grade stainless steel (or reflective material steel coating) would be more efficient than painted cold-rolled steel by approximately 0.5 percent.[96]

Although **combination microwave ovens** will not be analyzed due to difficulties in testing multiple cooking modes, a brief discussion will be included due to the potential energy efficiency improvement and increase in consumer utility under real-world conditions.

One of the primary limitations of microwave cooking is that the food load heats internally faster than the exterior, which is in contact with the relatively cold air in the oven cavity. This leads to an undesirable moisture distribution, where the exterior remains soggy when the interior is cooked. Therefore, methods have been developed to combine microwave with other modes of heating to mitigate surface moisture accumulation, provide a browning function that more closely replicates traditional cooking processes, and reduce overall cooking times.

Microwave and thermal or convection heating combines the features of a microwave oven and a conventional or convection oven. The GE Profile Oven with Trivection utilizes electric radiant heating elements augmented by convection and microwave systems to speed cooking. While it is possible to cook in conventional thermal mode with or without convection, the microwave function cannot be utilized alone. According to GE, cooking times can be reduced by 50–75 percent compared to a conventional oven for a wide variety of foods.[97] This oven is also advertised as compatible with all types of cookware including metal, glass, and stoneware.

Microwave and jet air-impingement is the combination of microwave energy delivery plus high velocity hot air impacting the food load. This technology is widely used in commercial combination ovens for preparing such food products as pizzas. A residential version of this type of oven began shipping in the fourth quarter of 2006.[r] According to *Appliance Design* magazine, the TurboChef Speed Cook Oven cooks up to 15 times faster than a conventional oven.[98] The air jets are arrayed at the top and bottom of the cavity, and those at the top pass through the magnetron mode stirrer fan to enhance uniformity. The oven also employs dual magnetrons and top and bottom electric heating elements for faster heatup and broil functions.

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 3.14.6 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

[r] For more information visit *http://www.turbochef.com*.

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. 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 oven power supply, that no-load power consumption improvement is approximately 0.4 W.

Switching power supplies offer the highest conversion efficiencies (up to 75 percent) and lowest no-load standby losses (0.2 W or less), though at a higher cost, higher part count, and greater complexity. Besides being as-yet unproven in long-term microwave oven applications, 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 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 EISA 2007 and IEC 62301 definition of "standby mode" 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.

3.14.2.2 Commercial Clothes Washers

For **commercial clothes washers**, DOE will consider technologies taken from its most recent analysis of amended energy conservation standards for residential clothes washers as well as from information provided in recent trade publications. Other than the exceptions noted hereafter, the following technologies are taken from a 1996 report prepared for DOE, entitled *Design Options for Clothes Washers*.[99] Steam washing and improved front-loading-washer drum design were identified in the September 2005 edition of *Appliance Magazine*.[100] DOE identified the low-standby-power technology option during its engineering analysis review of all AHAM product classes. Spray rinse and advanced agitator technology options were added in response to comments received by DOE following the Framework public meeting.

Technology options that allow CCW platforms to potentially reach higher efficiency levels are listed in Table 3.14.7.

Table 3.14.7 Technology Options for Commercial Clothes Washers

1. Adaptive control systems
2. Added insulation
3. Advanced agitation concepts for top-loading machines
4. Automatic fill control
5. Bubble action
6. Direct-drive motor
7. Electrolytic disassociation of water
8. Front-loading design with recirculation
9. Improved fill control
10. Improved front-loading-washer drum design
11. Improved water extraction to lower remaining moisture content
12. Increased motor efficiency
13. Low-standby-power electronic controls
14. Ozonated laundering
15. Reduced thermal mass
16. Spray rinse or similar water-reducing rinse technology
17. Steam washing
18. Suds saving
19. Thermostatically controlled mixing valves
20. Tighter tub tolerance
21. Ultrasonic washing

Adaptive control system

According to the DOE test procedure (10 CFR part 430, subpart B, appendix J1), "an adaptive control system refers to a clothes washer control system which is capable of automatically adjusting washer operation or washing conditions based on characteristics of the clothes load placed in the clothes container, without allowing or requiring consumer intervention or actions." This technology option uses sensors to measure the soil load to adjust the wash temperature, agitation and/or tumble cycle time, number of rinse cycles, spin speed, and other parameters. Water and energy use can then be tailored to the load, thereby avoiding washing the clothes more than necessary. Although the DOE test procedure does not provide a means for determining the energy consumption of a clothes washer with an adaptive control system, the test procedure does allow for specific field test procedures to measure energy consumption.

Residential clothes washers have used fuzzy logic to weigh laundry loads and regulate the length of the cycle, water level, number of rinses, and drying time.[101] Specific clothes washer designs have incorporated fuzzy logic to optimize the washing process while conserving water usage. The fuzzy-logic control determines the absorbency of the items being washed at the earliest stage possible after the start of the washing cycle. The system determines the correct water quantity for clear-water washing and subsequent rinsing.[102]

Added insulation

This technology option adds insulation around the outer wash tub. Because some heat energy is lost through the shell of the clothes washer, adding insulation around the outer tub slightly reduces the water temperature needed for a hot wash. However, since the wash cycle is relatively short and the thermal mass of the water is very high, there is very little change in water temperature from adding insulation. Computer simulations performed on a traditional top-loading clothes washer for a 20-minute wash cycle at 140 °F showed that adding 1 inch of fiberglass insulation relative to no insulation resulted in only a 1–2 °F increase in water temperature during parts of the wash.[103]

Advanced agitation concepts for top-loading machines

Advanced agitation concepts replace the standard agitator found in traditional top-loading machines with an alternative manipulator to agitate clothes and thus mechanically remove soil. In the residential clothes washer market, these alternatives to agitators have taken different forms, including nutating plates, rotating disks, and side-mounted agitators. In some instances, such agitation concepts allow a top-loading washer to avoid the need to cover all clothes completely with water, rotating them in and out of the water-filled portion of the basket, much like front-loading washers. Advanced agitation systems add considerable complexity to a top-loading clothes washer, and residential clothes washers that feature these technologies are sold for prices comparable to front-loading clothes washers.

Since the DOE test procedure captures the amount of water that a clothes washer consumes, the benefits of an advanced agitation concept washer can be directly measured and quantified via the WF. Potential energy savings are captured by the MEF as long as a portion of the washing cycle consumes heated water.

Automatic fill control

This technology option incorporates advanced control technologies to sense the clothes load and adjust the water level accordingly. For a traditional top-loading machine, this may mean setting the water level to just submerge the clothes load. This technology option can overcome the tendency of consumers to manually select a water level greater than required for a given load.

The implementation of this feature varies. While this feature is inexpensive to implement in all front-loading washers, top-loading washers do not benefit from the same advantages regarding drum geometry and rotation axis.[s] As a result, automatic fill control is typically only found in higher-end top-loading models that have electronic controls and proprietary designs, limiting adoption to a small percentage of the top-loading market. Energy is saved in either top- or front-loading designs by reducing the amount of hot water used in the wash cycle.

Bubble action

Daewoo has developed an air-bubble washing machine. This machine uses a low-profile impeller typical in Asian-style top-loading washers and combines it with a six-winged, rotating pulsator shaped to direct water in four directions. This pulsator also distributes air bubbles in different directions. The bubbles are generated by a vibrating bellows, which is driven by an electromagnet. Bubbles are reported to increase the cleaning power of the washer in several ways: (1) by inducing a high-frequency pressure fluctuation near the clothes, (2) by increasing the dissolution of detergent, (3) by increasing the amount of dissolved oxygen which increases the activity of the detergent, and (4) by lowering the viscosity of the wash water.[104, 105] Daewoo washers that utilize air-bubble washing action are available in the European market, but are not available to U.S. consumers.[106]

Sharp also developed a bubble washer in which the bubble-generating device uses neuro-fuzzy-logic controls. From a nozzle located at the bottom of the washer, air bubbles are generated by a computer-controlled pulsator and circulated upward in vertical and horizontal swirling motions. The controls adjust the amount of water used, so that a single-tub design that washes the same load size as a conventional dual-tub (inner and outer) configuration uses only. 70 percent as much water and detergent.[107] Although it is mentioned on the manufacturer's website, this washer is not available in the U.S.[108] Standardized and independent tests have yet to be conducted on the performance of the bubble-action system; therefore, the energy savings potential and wash performance of the bubble-action technology option is unknown.

Although bubble washing has been incorporated into commercial products in Europe and Asia, production is still extremely limited and further commercialization in the U.S. would require manufacturers to develop entirely new platforms.

Direct-drive motor

This technology option is primarily intended for use in traditional top-loading machines. A traditional top-loading clothes washer uses an induction motor, a mechanical transmission, and

[s] Front-loading washers can incorporate a fill switch in the sump to monitor water levels as the wash basket and its contents are rotated slowly at the beginning of the wash cycle. As dry clothes drop into the wash water, they absorb some of it and the water level in the sump drops. The fill switch then opens the fill valve(s) to raise the water level until the sump is full again. This approach does not work with top-loading washers because the clothes are always immersed in the water. Proprietary solutions have been implemented on some top-loading washers, however.

sometimes a pulley belt. A direct-drive motor can replace this conventional motor/transmission system. Rather than using a belt and/or transmission, a motor could be directly connected to the agitator, thereby avoiding transmission (gearbox) losses. In the past, Eaton, a motor manufacturer, claimed that this will result in less mechanical energy required, *i.e.*, less energy needed to run the agitator motor. This is accomplished by using a brushless direct-current (BLDC) motor with electronic controls.

Potential differences in cleaning performance due to the direct-drive substitution were not measured by Eaton. In addition, other parameters such as cycle time or spin speed were not held constant in a comparison test with a conventional washer. For the machines tested, Eaton found savings of about 140 Wh per cycle, or 64 percent of motor energy use[109].

In the past, some manufacturers have stated that a limiting performance factor for this technology option was physical size. However, GE uses direct-drive motors on some of their residential top-loading washers.[110] Fisher & Paykel manufactures two top-loading direct-drive washing machines available in the U.S. market.[111] Some front-loading machines also use a direct-drive motor, including models manufactured by LG.[112]

Electrolytic disassociation of water

The goal of electrolytic disassociation of water is to reduce hot water usage by substituting the electrolytic production of bleaching agents for activation of bleaching chemical reactions in detergents by hot water. A prototype clothes washer with electrolytic disassociation of water has been successfully tested.[113] Although commercial detergents perform better at high temperatures, the same hypochlorite concentrations obtained by adding bleaching agents to water can be achieved at low temperatures if the agents are produced by electrolytic disassociation within the machine. The bleaching action is due to the chemical reaction of the oxygen (derived from the chemical decomposition of the hypochlorite) with the insoluble organic compounds that constitute the soil in the clothes. Together they make soluble compounds that are dissolved in the water.

Electrolytic disassociation was tested in a laboratory electrochemical cell. Medium-soiled clothes and white materials were used in the test. The washing cycle test compared the energy consumption of electrolytic cleaning versus conventional detergents. The first test cycle, utilizing electrolytic action, was performed by adding four grams per liter of salt to the room-temperature wash water in the machine. The second test cycle was run with a commercial detergent at a wash water temperature of 95 °F to 113 °F. For both wash methods, a normal cycle was run. Initial tests showed that energy use dropped from about 2.65 kWh/cycle for a typical washing machine to 1.35 kWh/cycle for the new electrochemical method. This technology is still at the research stage.

In the past, manufacturers have stated that electrolytic disassociation is not a workable approach. Primary concerns are negative effects on garments resulting from the bleaching process and poor consumer acceptance due to their inability to control the chemistry and temperature in the wash portion of the cycle.[114]

Front-loading design with recirculation

This technology option for front-loading washers uses a small pump to recirculate water out of the sump and spray it into the drum. The small amount of standing water in a standard front-loading washer is thus further minimized. Less hot water is needed per wash cycle, thereby saving energy.

In the previous residential clothes washer rulemaking, manufacturers commented that they have not been able to verify that a savings exists with recirculation.[115] Limiting factors mentioned by these manufacturers include (1) soil removal, (2) tangling, (3) cycle time, (4) rinsing, and (5) suds sensitivity.

In the past, Electrolux has produced models that sprayed 8 liters per minute of water/detergent solution into the drum by means of a supply valve above the door.[116]

Improved fill control

This technology option is defined as improving the tolerance on existing wash-water fill sensing, which can be accomplished by reducing tolerances of presently used pressure sensors or improving switch design. This technology option relates primarily to top-loading washers, although it is sometimes applicable to front-loading washers, depending on the fill control used on the washer design.

In a traditional top-loading washer, one end of an air hose is connected to an air chamber near the bottom of the washer tub and the other end is connected to a pressure switch. As water fills the tub, air in the hose and chamber is forced into a smaller volume, thereby increasing the air pressure. The air pressure increases until it activates a pressure switch, which in turn shuts off the water inlet valve. A more accurate water-level-setting system would avoid overfilling the wash tub, thereby reducing the amount of water and energy used. In the past, manufacturers have stated that they were not aware of any opportunity to reduce tolerances of pressure sensors.[117]

Improved front-loading-washer drum design

Manufacturers of front-loading washers continue to research and modify existing drum designs to improve wash performance, reduce mass, and increase spin speeds. With each drum revision, manufacturers frequently make claims that their drum designs increase consumer utility by being gentler on clothes or by reducing the cycle time through better agitation of the clothes in the washer. A reduction in cycle time would have a measurable impact on washer power consumption, just as drums that can sustain higher spin speeds can reduce the remaining moisture content (RMC) and thus raise the MEF of a washer.

RMC is defined as:

$$RMC = \frac{(WC - WI)}{WI}$$

where WC is the weight of the test cloth immediately after completion of the washer spin cycle, and WI is the "bone dry" weight of the test cloth.

Implementation of this technology option varies, with drums featuring special paddles, drum-wall textures, or similar enhancements.

Improved water extraction to lower remaining moisture content

There are several ways to reduce the RMC, including: (1) increasing the spin speed of the wash basket for the final spin cycle; (2) changing the direction of rotation to more evenly distribute clothes; (3) having a longer spin cycle; and (4) increasing the size or number of drainage holes in the washer drum. Since mechanical water removal is more energy efficient than using heat to dry, energy consumption for the combined wash and dry process is reduced.

The DOE test procedure assumes that the improved-water-extraction feature will not be used for 25 percent of all wash cycles. Since this feature can be consumer selectable, clothes subject to wrinkling can be washed with a conventional spin-cycle option to avoid a wrinkling problem. Some manufacturers in the past were doubtful that RMCs of 35 percent and 30 percent could be practically obtained.

At the time of the 2001 TSD, laboratory testing was conducted to ascertain RMCs on commercially-available front-loading washers. Measured RMCs ranged from 49 percent to 36 percent with a 50/50 cotton/polyester cloth load. For the same test load, a top-loading machine had a 52 percent RMC. The washers for the above testing were loaded at 3 lb/ft^3 of basket capacity.[118] The DOE test procedure, however, specifies the test load as being closer to 4 lb/ft^3 of basket capacity. Since the size of the cloth test load has an effect on the RMC achieved, it is unknown whether the above laboratory-tested machines can achieve their stated RMC values under DOE test conditions. As of the 2001 TSD, clothes washers with a certified RMC of up to 40 percent were available.[119]

RMC data are no longer required to be published because the current test procedure requires the publication of only the MEF and WF for clothes washers. RMC data can be found in the CEC CCW database, but this database does not cover all CCWs on the market, nor is it completely current. Thus, DOE is unable to determine the water extraction capabilities of all CCWs that are currently on the market. Supporting the 2001 TSD manufacturer comments indicating skepticism towards achieving practical lower RMC values, none of the clothes washers listed in the CEC CCW database has an RMC below 39 percent. Top-loading CCWs typically feature an RMC of about 50 percent, while front-loading clothes washers typically feature an RMC of about 40 percent, according to the DOE test procedure.

Increased motor efficiency

About 10 percent of the total electrical energy consumed by a typical clothes washer is used by the electric motor. The typical washing machine has a ½ –⅔ horsepower motor. In the past, a residential clothes washer manufacturer stated that replacing a split-phase motor with a capacitor-start motor may increase the efficiency of the motor by 10 percent.[120] Permanent magnet motors offer even higher efficiencies, though the benefit of a higher efficiency motor has to be balanced with the higher cost and the relatively small contribution to the overall energy consumption per wash cycle from the motor itself.

Low-standby-power electronic controls

Electronic controls may consume power even when the clothes washer is not performing its intended function. Depending on the implementation of the controller, standby power is required to enable the electronic controls to detect user input without the user first having to turn on a mechanical power switch or to enable displays, illuminate switches, etc. Reducing the standby power consumption of electronic controls would reduce the annual energy consumption of the clothes washer, but would not impact the energy consumption of the clothes washer during operation. Low-standby-loss electronic controls can be implemented in a wide variety of ways. DOE is unaware of any data demonstrating energy savings associated with low-standby-power designs for CCWs.

Ozonated laundering

Ozonated laundering systems are available for large-scale commercial or institutional use. The ozone, manufactured from ambient air, is injected into the water. There is some debate as to how the process of the ozonated cleaning exactly works. Some claim the ozone reacts with soluble soils, making them insoluble, after which the mechanical action of the washing separates the soils from the fabric. One manufacturer proposed that the energy inherent in ozone reduces water tension, making the water a better solvent. Energy is saved with this system because the water is not heated for lightly to moderately soiled laundry. In fact, colder water retains a higher concentration of ozone for a longer time than warmer water. For heavily soiled laundry, temperatures of 100–110 °F are used, which are lower than the temperatures required in a conventional washer. Also, since fewer chemicals are used, the rinse time is minimized, thereby reducing the total cycle time and water consumption. Economical ozone production is critical to the potential energy savings. One manufacturer estimates savings of 25 percent on "utility expenses" with installation of its system.[121] However, in addition to the ozone generator, a new or reprogrammed controller would be required, adding to the cost of this technology option.

Reduced thermal mass

This technology option uses a plastic tub specially designed to minimize the thermal mass that is heated by the water. Tests by manufacturers indicate that very little energy can be saved this way because the bulk of the thermal mass is contained in the hot water itself. One manufacturer compared the impact of both porcelain-enameled steel and polypropylene outer tubs on water temperature. Both machines were filled with 16 gallons of 140 °F water and agitated for 10 minutes. After 10 minutes, there was no significant difference in water temperature between the two machines. Calculations show that if there were no heat losses through the outer tub, the equilibrium temperature for the tested steel tub described above would be 138.9 °F. Therefore, there is little to be gained by decreasing the thermal mass of the outer tub.[122]

Plastic outer tubs are commonly used by manufacturers and can be considered as part of the baseline model. There is no practicable way to manufacture washing machines with plastic tubs with a lower thermal mass beyond the current practice.

Spray rinse or similar water-reducing rinse technology

Traditional top-loading clothes washers immerse the clothing completely in water during the wash and rinse phases of the cleaning cycle. Spray-rinse systems eliminate the immersion requirement by spraying rinse water into the drum while the wash basket is rotating. The centrifugal force of the rotating basket pins the clothes against the outer walls and subsequently forces the rinse liquid through the clothes. In the process, the rinsing liquid picks up remaining suds and transports them into the sump, from which they are drained. Since immersion or partial immersion is no longer necessary, less rinse water is required. When using hot rinse water, this reduces energy consumption by reducing the amount of hot water required for the rinse cycle. DOE is unaware of any commercial top-loading clothes washers currently available that utilize spray rinse.

Manufacturers caution that spray rinse or similar rinse-water reduction technology options are not embraced by all customers. For example, spray rinse technologies allegedly do not function well if a washer is overloaded, requiring a consumer behavior change which is more easily achieved in a residential than a commercial setting. Previously available top-loading CCWs with spray rinse technology were withdrawn from the market, though another manufacturer recently introduced a spray-rinsing CCW.

AHAM may develop a rinse performance standard for clothes washers that could preclude the use of rinse-water reduction technologies. The current DOE test procedure, though, captures the benefit of this technology option, as any reduction in water consumption improves WF and any reduction in heated water consumption improves MEF.

Steam washing

With steam washing, steam is sprayed on the laundry to help clean and sanitize the clothes without requiring the tub to be filled with water that is heated to sanitizing temperatures. Since less water must be heated to complete a steam washing cycle compared to a traditional washer, which immerses clothes in hot water, steam washing can reduce the energy and water consumption of clothes washers.[123]

LG began offering two residential clothes washers in the U.S. market that use steam washing in 2005, and Whirlpool launched a steam clothes washer in the United States in 2008. [124,125] All models are ENERGY STAR-qualified.

Suds saving

A suds-saving feature allows water from one wash cycle to be reused in the next wash cycle. After agitation, sudsy wash water is pumped into a separate storage tub, remaining there until the next wash cycle. While the water is stored, soil settles to the bottom of the tub. During the next wash cycle, all but an inch of the water is pumped back into the washer tub for use again[126]. Manufacturers believe that there is low consumer demand for this option and it would therefore not be used often. In addition, this option cannot be used for all loads or soil conditions. This option is useful only when there is more than one wash cycle per load of laundry, *e.g.*, a pre-wash (which is not typically the case), or if the consumer washes more than one load in sequence. Subsequent washes could receive diminishing benefits if they are not completed immediately after the previous load, since the water in the holding tub would cool if left standing too long. Another limiting performance factor mentioned by more than one manufacturer for this technology option was soil removal. In addition, because this option requires an adjacent external wash tub to store suds in between wash cycles, consumer utility is affected. In a commercial setting, this could limit the number of clothes washers that may be installed.

This technology option is no longer commercially available. Electrolux formerly had a residential model that saved water from the final rinse of one load to use again as the prewash of the next cycle[127]. Maytag had also featured this technology as a water saving option on one of its washers. However, neither model is still in production.

Thermostatically controlled mixing valves

Thermostatically controlled water valves (TCWVs) are defined by the DOE test procedure as “clothes washer controls that have the ability to sense and adjust the hot and cold supply water.” This technology option achieves energy savings by more accurately controlling inlet water temperature for hot and warm fills. In a typical non-thermostatically-controlled water inlet system, two solenoid valves are used; one valve opens for hot water fills while the other opens for cold water fills. Both solenoid valves are opened if a warm water setting is selected. In the warm wash mode, fixed fractions of hot and cold water are controlled by flow-control devices. For example, a manufacturer may decide to specify warm water as 50 percent hot water and 50 percent cold water. To reduce hot water energy use, some manufacturers have reduced the warm water temperature by using other ratios such as 40 percent hot and 60 percent cold.

Energy can be saved with a TCWV by either reducing the hot water temperature and/or reducing the warm water temperature. For example, the TCWV could be used to lower the hot wash temperature from 135 °F to 130 °F by mixing hot water (at 135 °F test inlet conditions) with cold water. Warm water temperature could be similarly reduced. The energy savings can vary widely depending on the test standard's specified inlet hot water temperature and the selected temperature of the warm water.

The TCWV technology option has the potential to overstate the real-world energy savings, depending on the proximity of the water heater to the installed clothes washer. When tested under laboratory conditions, the clothes washer is typically close to the hot water source, whereas this is generally not the case in either a residence or commercial laundry setting. As a result of the distance between the hot water source and the clothes washer, there is a temperature drop due to line losses. Because of these line losses, a clothes washer with a TCWV may use more hot water than predicted on the basis of laboratory testing. Similarly, in a real-world application, savings will also vary with the temperature of incoming cold water. The unheated water temperature will vary with both geographic location and time of year. More energy would likely be saved in cases of warmer "cold" supply water, as a TCWV would then reduce the amount of time a hot water valve is open. The amount of savings is also dependent on the set point of the TCWV, the water heater set point, the temperature selection of the wash (hot or warm cycle), and the location of the sensing thermostat controlling the inlet water valves. A limiting performance factor mentioned by more than one manufacturer is soil removal with lower wash temperatures.

Tighter tub tolerance

This technology option reduces the annular volume between the inner wash basket and the outer tub. This annulus fills with water, but does not add to the clothes washer capacity. Having less space between the inner wash basket and the outer tub reduces the amount of water required for a fill, thereby saving the energy required to heat that water. This option applies primarily to traditional top-loading washers. In a high-efficiency top-loading or front-loading washer, water only occupies the lower portion of the annulus. Since most of the annulus in a high-efficiency top-loading or front-loading washer is filled with air, a smaller annulus does not yield significant energy savings.

Other considerations are also important in determining an appropriate clearance between basket and tub. In the past rulemaking, residential clothes washer manufacturers stated that if the annulus is too small there may be problems with "suds lock", where suds from the wash water remain between the inner wash basket and outer tub. Clearance is also needed to drain water during the spin-dry cycle and to allow for deflection of baskets with out-of-balance loads. Increasing the spin speed of the washer basket during the spin dry cycle may also require a larger space between tub and basket to allow for greater deflection at higher spin speeds. For this latter reason, tighter tub tolerance was not combined with the improved-water-extraction technology option. Other limiting performance factors mentioned by residential clothes washer manufacturers in the past include: (1) noise; (2) vibration; and (3) sand removal.

Ultrasonic washing

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

One of the problems with ultrasonic washing is that clothes are not uniformly exposed to the vibrations generated by the transducers, which means that some areas may remain soiled. Additionally, the wash solution and the submerged clothes appear to dissipate much of the energy without the clothes being cleaned. A design producing adequate cleaning action does not appear to have been developed.[128]

3.14.3 Energy Efficiency

In preparation for the screening and engineering analyses, DOE gathered data on the energy efficiency of residential cooking products and CCWs 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 each product covered by this rulemaking.

3.14.3.1 Cooking Products

Conventional Cooking Products

The DOE test procedure for cooktops is based on measuring the amount of energy required to raise an aluminum test block from room temperature to a specified temperature above room temperature. Of the efficiency data available, many are based on tests measuring the amount of energy that is required to boil a specified amount of water. The amount of water and length of time to boiling varies, depending on the researcher or manufacturer conducting the test. In addition, boil times vary with altitude, as increasing altitude decreases the length of time required to boil water. Only efficiency data based on the DOE test are used in the analysis because “boiling water” tests being conducted currently do not use a standardized water load or boiling time.

Although not completely representative of the current U.S. cooking products market, Natural Resources Canada (NRCan) publishes a database of electric cooking appliance performance as measured by the applicable Canadian Standards Association test procedures. This database covers products available in the Canadian market, which overlaps with the U.S. market. Data from the NRCan database are presented as the distribution of listed models as a function of EF, which is calculated by dividing the annual useful cooking energy output from the DOE test procedure by the rated annual energy consumption from the database.

Figure 3.14.1 displays the EFs of standard open (coil)- and smooth element electric ranges listed in the NRCan database.

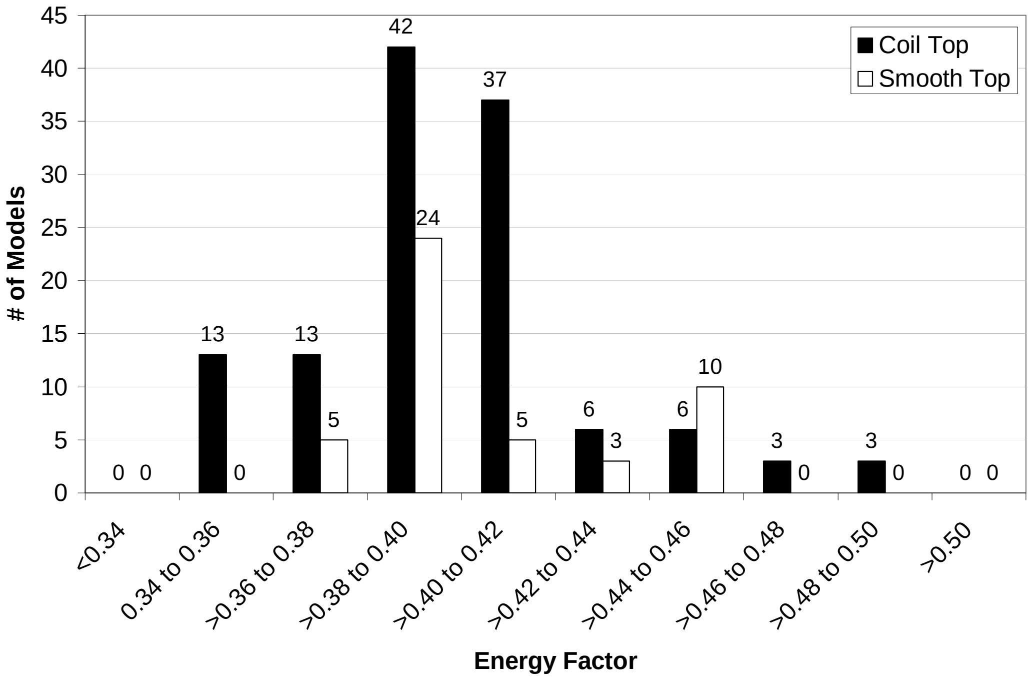

Figure 3.14.1 Standard Electric Ranges in the NRCan Database[129]

Figure 3.14.2 displays the EFs of self-cleaning open (coil)- and smooth-element electric ranges listed in the NRCan database.

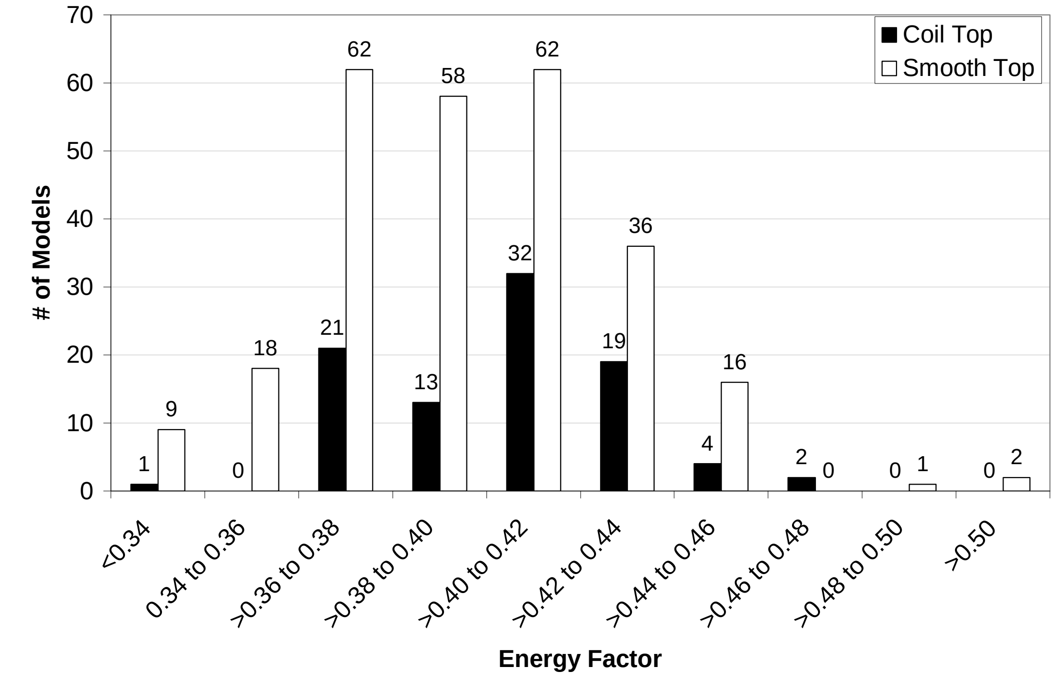

Figure 3.14.2 Self-Cleaning Electric Ranges in the NRCan Database[130]

Figure 3.14.3 displays the EFs of open (coil)- and smooth-element electric cooktops listed in the NRCan database.

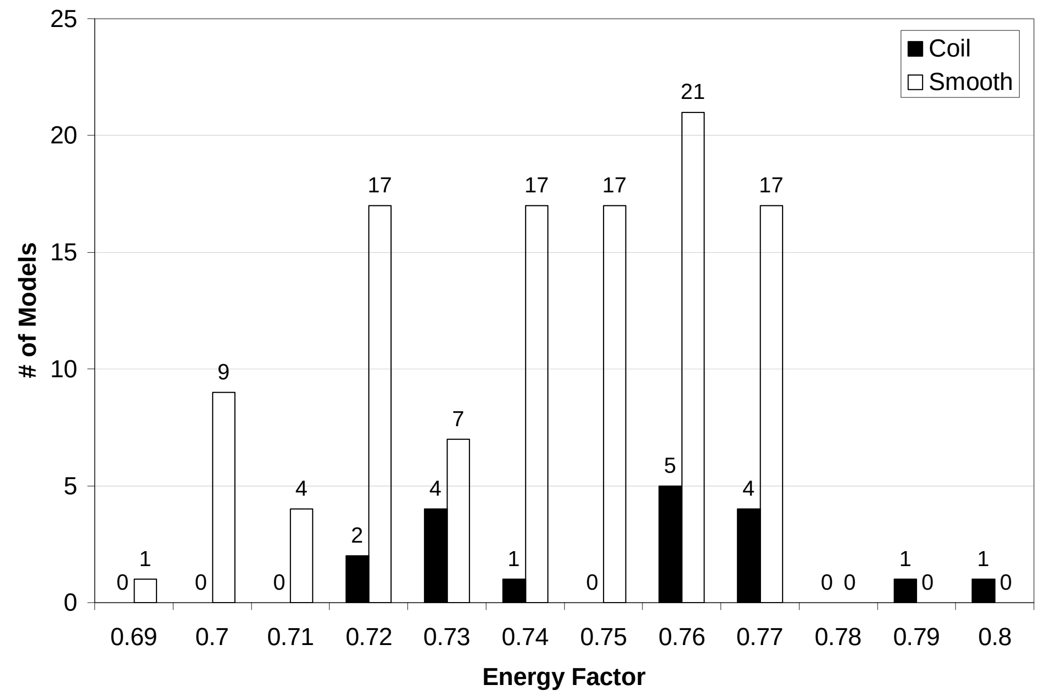

Figure 3.14.3 Electric Cooktops in the NRCan Database[131]

Figure 3.14.4 displays the EFs of self-cleaning electric ovens listed in the NRCan database for both single and double ovens, while Figure 3.14.5 displays the EFs of non-self-cleaning electric ovens listed in the NRCan database for both single and double ovens.

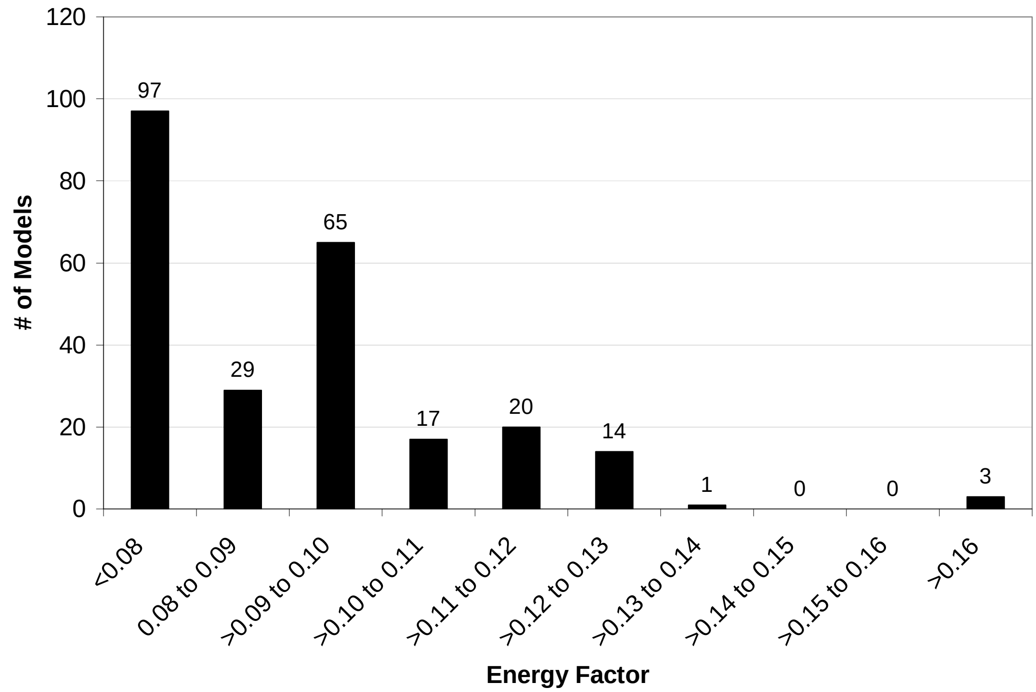

Figure 3.14.4 Self-Cleaning Electric Ovens in the NRCan Database[132]

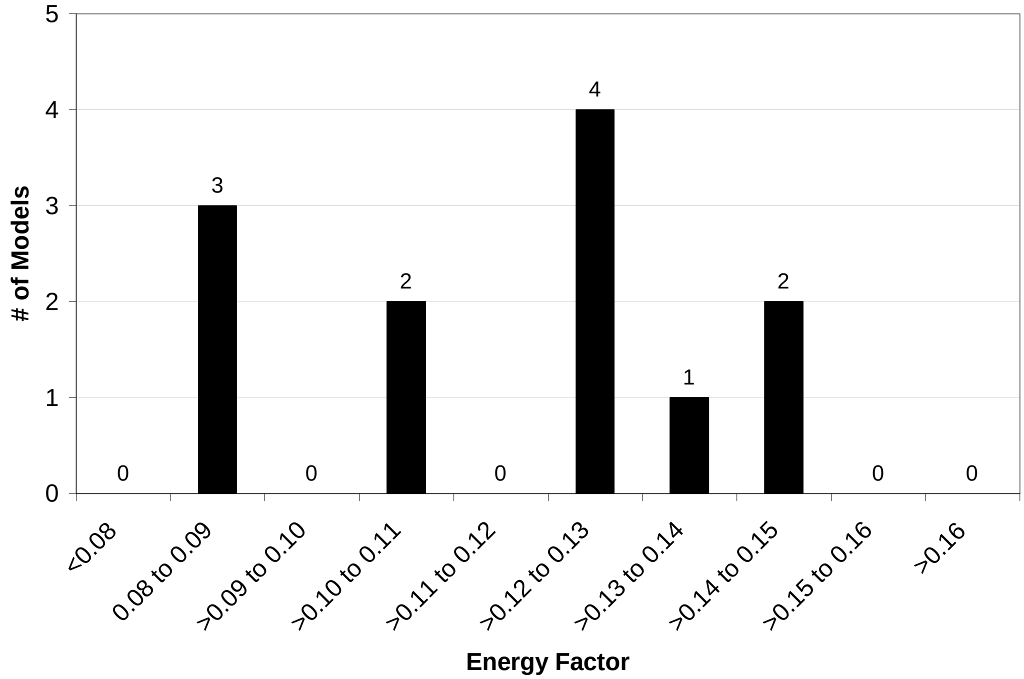

Figure 3.14.5 Non-Self-Cleaning Electric Ovens in the NRCan Database[133]

While self-cleaning ovens tend to be more efficient than non-self-cleaning ovens, due to the thicker insulation required to maintain safe exterior temperatures during oven cleaning cycles, some non-self-cleaning ovens exhibit EFs comparable to self-cleaning electric ovens. However, no non-self-cleaning electric ovens have EFs above 0.15, while three self-cleaning electric ovens have EFs exceeding 0.16.

Microwave Ovens

For microwave ovens, the DOE test procedure utilizes the test procedures specified in IEC 705. It should be noted that IEC 705 has been superseded by IEC 60705. DOE does not plan to revise the test procedure to incorporate IEC 60705 to measure the cooking efficiency because, as discussed in chapter 5 of the TSD, DOE conducted analyses on a sample of microwave ovens which indicated that the efficiency measurements obtained with IEC 705 were more stable and repeatable than those obtained using IEC 60705.

Microwave ovens consume energy in cooking mode, when heating food, and in standby mode, while powering the clock and electronic controls. AHAM recently provided data on microwave oven efficiency and standby power for a sample of microwave ovens available in the U.S. market.[134] Microwave oven efficiency was tested according to DOE's test procedure. Standby power was tested according to IEC 62301. Although AHAM only tested 21 units from 9 manufacturers, the units were selected to represent a broad spectrum of units available in the market place, and had varying capacities and features. Figure 3.14.6 and Figure 3.14.7 display the AHAM microwave oven efficiency data.

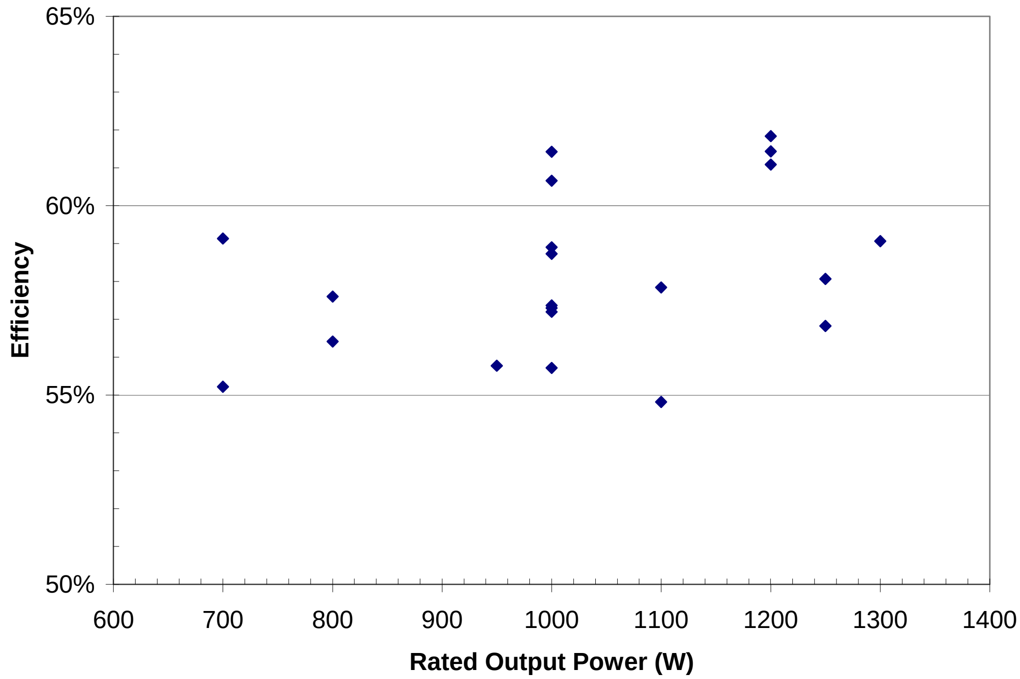

Figure 3.14.6 AHAM Microwave Oven Efficiency versus Rated Output Power[135]

Figure 3.14.6 illustrates the lack of a correlation between microwave oven rated output power and microwave oven efficiency. Efficiency remains nearly linear across the tested output power range. Figure 3.14.7 illustrates the relationship between microwave oven volume and microwave oven efficiency. Again, microwave oven efficiency remains constant and nearly linear regardless of microwave oven volume.

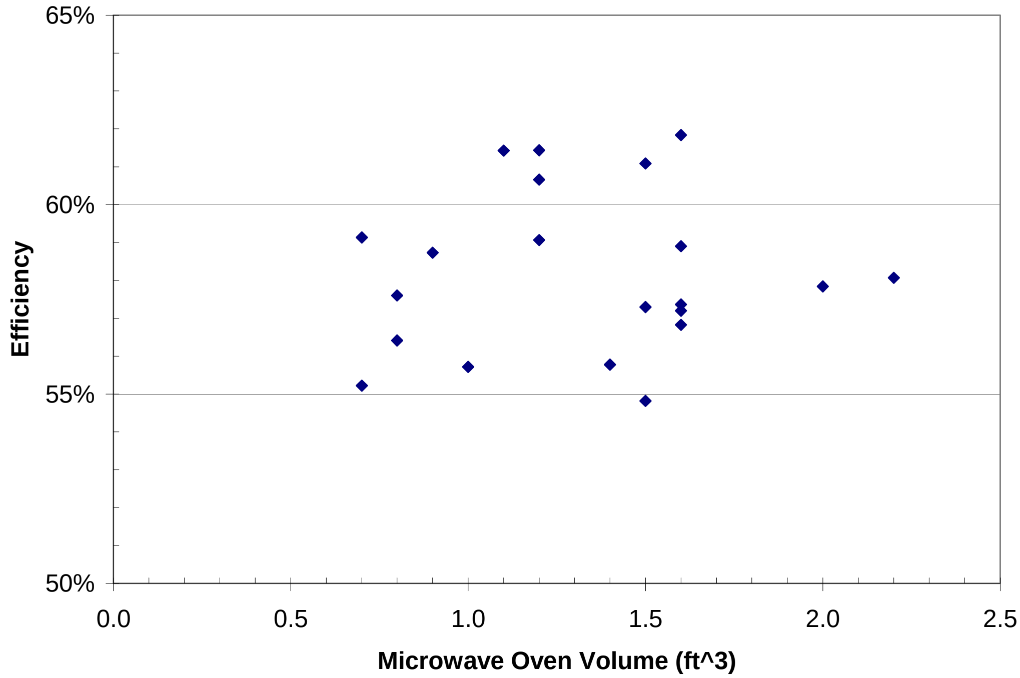

Figure 3.14.7 AHAM Microwave Oven Efficiency versus Oven Volume[136]

Figure 3.14.8 displays AHAM-measured microwave oven standby power data as a function of rated output power. Figure 3.14.8 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 output power.

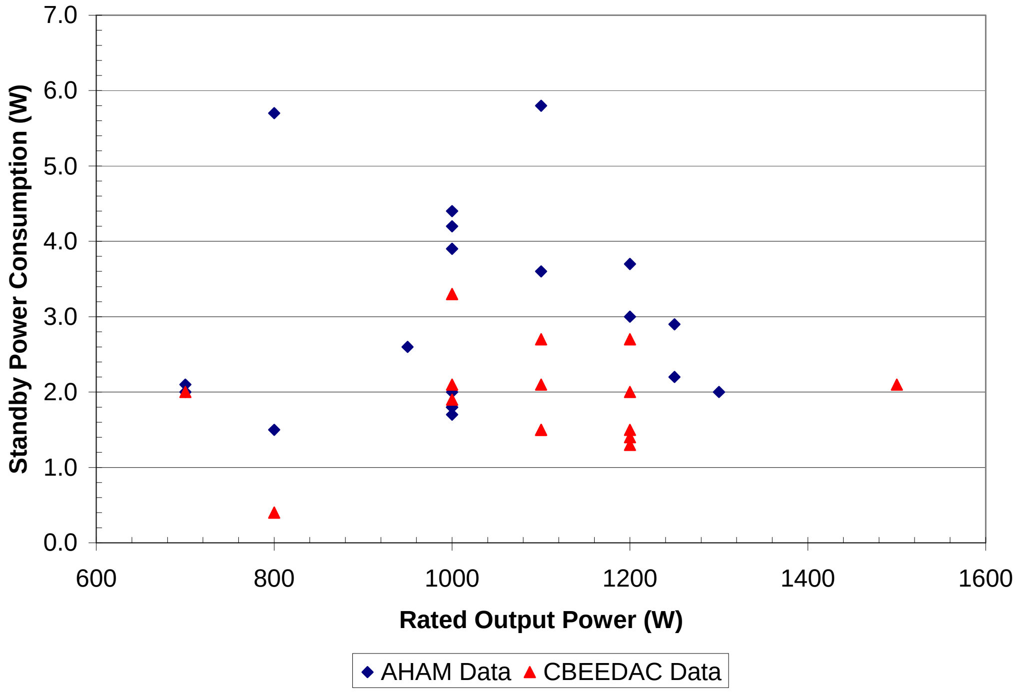

Figure 3.14.8 AHAM and CBEEDAC Microwave Oven Standby Power versus Rated Output Power[137,138]

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 3.14.9 displays the number of microwave oven models available with different standby power levels as listed in the FEMP standby power database.

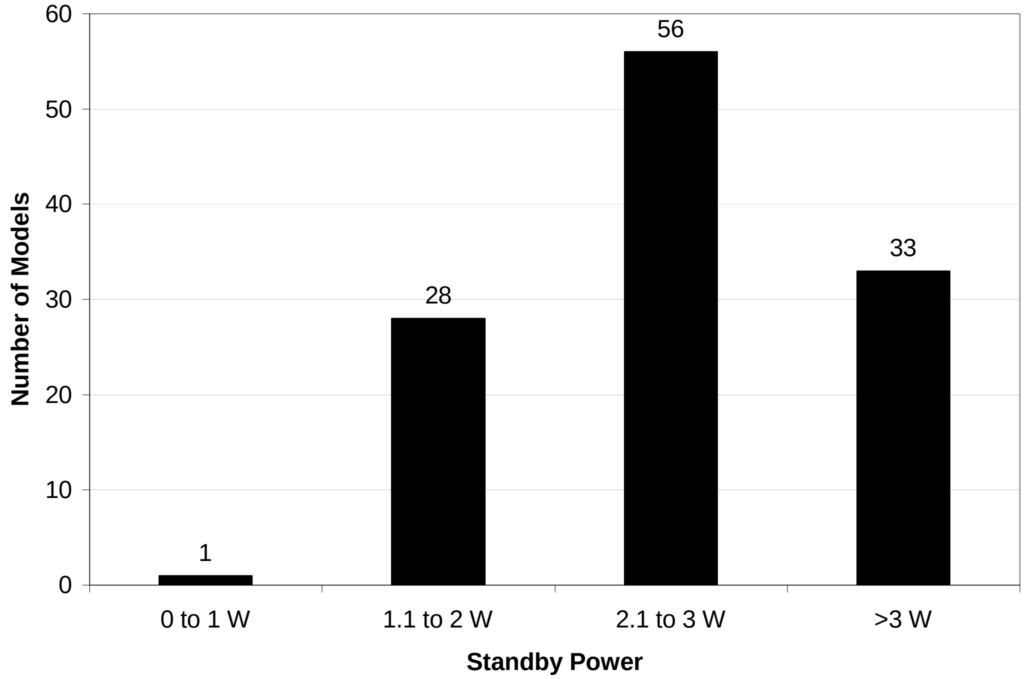

Figure 3.14.9 Microwave Oven Standby Power Consumption from the FEMP Database[139]

FEMP does not specify microwave oven rated 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. Very few 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.

3.14.3.2 Commercial Clothes Washers

Although not completely representative of the current CCW market, the CEC publishes a list of "certified" products. Even though the Federal standard only recently was raised to an MEF of 1.26, California had previously enacted a minimum standard at that level, so the database only contains products with MEFs of 1.26 and higher. ENERGY STAR and CEE also publish lists of certified products. Figure 3.14.10 displays the distribution of CCWs in the combined CEC, ENERGY STAR, and CEE databases as a function of MEF.

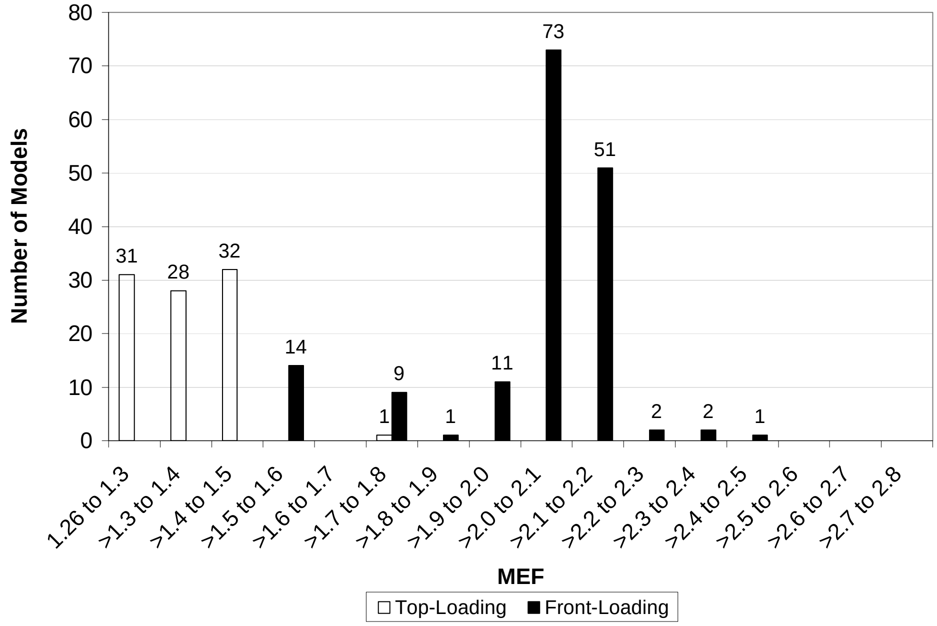

Figure 3.14.10 Commercial Clothes Washer MEFs in the CEC, ENERGY STAR, and CEE Databases[140 141 142]

Figure 3.14.10 illustrates the difference in MEF between top-loading CCWs and front-loading CCWs. All of the CCWs with an MEF below 1.5 are front-loading units, whereas all but one of the washers with an MEF above 1.5 are front-loading washers. No commercial top-loading washer has an MEF above 1.76, while 129 front-loading commercial washer models have an MEF above 2.0.

The CEC, ENERGY STAR, and CEE databases of certified CCWs also contain data on WF. The databases contain products with WF of 13 or lower. Figure 3.14.11 displays the distribution of CCWs in the combined CEC, ENERGY STAR, and CEE databases as a function of WF.

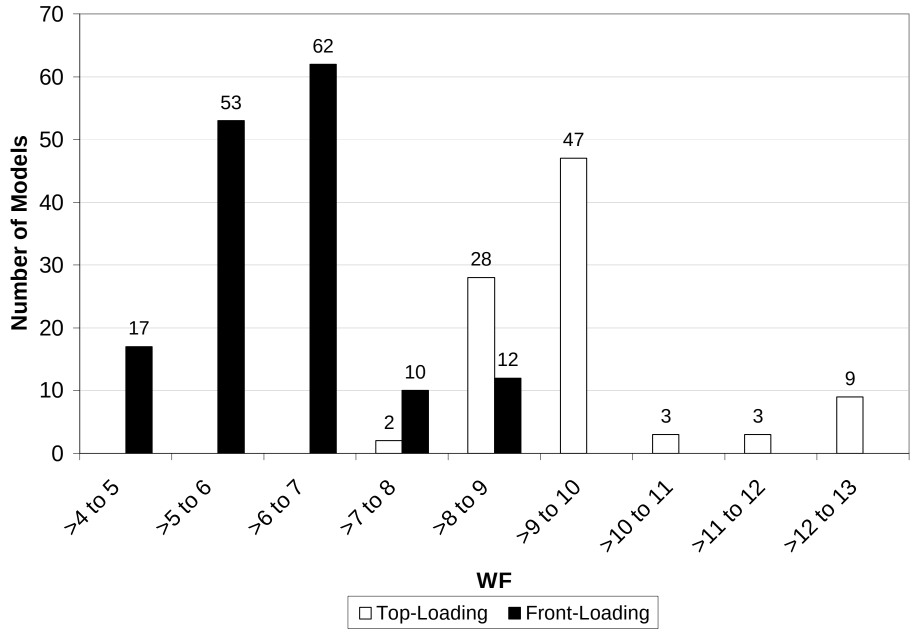

Figure 3.14.11 Commercial Clothes Washer WFs in the CEC, ENERGY STAR, and CEE Databases[143 144 145]

Figure 3.14.11 illustrates the difference in WF between top- and front-loading CCWs. All of the CCWs with a WF greater than 9.0 are top-loading units, whereas all of the washers with WF below 7.0 are front-loading units. No top-loading CCW has a WF below 7.0, while 132 front-loading models have a WF below 7.0.

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