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 dishwasher industry 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 DEFINITION

DOE defines “dishwasher” under the Energy Policy and Conservation Act (EPCA) of 1975 (42 U.S.C. 6291–6309) as “a cabinet-like appliance which with the aid of water and detergent, washes, rinses, and dries (when a drying process is included) dishware, glassware, eating utensils, and most cooking utensils by chemical, mechanical and/or electrical means and discharges to the plumbing drainage system.” (10 CFR 430.2)

3.3 PRODUCT CLASSES

DOE separates dishwashers into two product classes. 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 dishwashers, the size of the unit significantly impacts the energy consumed. In other words, standard-size dishwashers with relatively greater water consumption have significantly greater energy use than compact units. Because standard dishwashers offer enhanced consumer utility over compact units (*i.e.*, the ability to wash more dishes), DOE has established the following product classes, which are based on the size of the dishwasher (as specified in American National Standards Institute (ANSI)/Association of Home Appliance Manufacturers (AHAM) Standard DW-1-1992, *Household Electric Dishwashers*):

- Compact, (capacity less than eight place settings plus six serving pieces); and
- Standard, (capacity equal to or greater than eight place settings plus six serving pieces).

3.4 PRODUCT TEST PROCEDURES

DOE's test procedure for dishwashers is found in the Code of Federal Regulations (CFR) at 10 CFR part 430, subpart B, appendix C. DOE originally established its test procedure for dishwashers in 1977. 42 FR 39964 (August 3, 1977). In 1983, DOE amended the test procedure to revise the representative average-use cycles to reflect consumer use and to address dishwashers that use 120 degree Fahrenheit (°F) inlet water. 48 FR 9202 (March 3, 1983). DOE amended the test procedure again in 1984 to redefine "water heating dishwasher." 49 FR 46533 (November 27, 1984). In 1987, DOE amended the test procedure to address models that use 50 °F inlet water. 52 FR 47551 (December 15, 1987). In 2001, DOE revised the test procedure's testing specifications to improve testing repeatability, change the definitions of "compact dishwasher" and "standard dishwasher," and reduce the average number of use cycles per year from 322 to 264. 66 FR 65091, 65095–97 (December 18, 2001).

In 2003, DOE again revised the test procedure to more accurately measure dishwasher efficiency, energy use, and water use. The 2003 dishwasher test procedure amendments included the following revisions: (1) the addition of a method to rate the efficiency of soil-sensing products; (2) the addition of a method to measure standby power; and (3) a reduction in the average-use cycles per year from 264 to 215. 68 FR 51887, 51899–903 (August 29, 2003). The current version of the test procedure includes provisions for determining annual energy use expressed in kilowatt-hours (kWh) per year, estimated annual operating cost, energy factor (EF) expressed in cycles per kWh, and water consumption expressed in gallons per cycle. (10 CFR 430.23) DOE is currently considering amendments to the test procedure to further address standby mode and off mode energy consumption.

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 dishwasher industry, DOE researched various associations available to manufacturers, suppliers, and users of such equipment.

The Association of Home Appliance Manufacturers[a] (AHAM), 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 *Major Appliance 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.

[a] For more information, please visit www.aham.org.

3.6 MANUFACTURER INFORMATION

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

3.6.1 Manufacturers and Market Shares

Using publicly available data (*e.g.*, *Appliance Magazine* and market assessments done by third parties), DOE estimates the domestic market shares for dishwasher manufacturers. Manufacturers may offer multiple brand names. Some of the brand names come from independent appliance manufacturers that have been acquired over time, and domestic manufacturers may put their brand on a product manufactured overseas.

For residential dishwashers, DOE estimates that there are approximately 18 manufacturers supplying the domestic market. In 2008 (the most recent year for which market share data were available), nearly the entire market, or 94 percent, was controlled by three domestic manufacturers: Whirlpool, General Electric (GE), and AB Electrolux (under the Frigidaire brand[b]). The merger between Whirlpool and Maytag resulted in the combined company accounting for 49 percent of the domestic dishwasher market in 2008. BSH Home Appliances Corporation accounted for five percent of the total market in 2008, and the remaining one percent is made up of companies including ASKO Appliances, Inc. (ASKO), Dacor Inc. (Dacor), Equator Corporation (Equator), Fagor America Inc. (Fagor), Fisher & Paykel Appliances Limited (Fisher & Paykel), Haier America Trading, LLC (Haier), Miele, Inc. (Miele), Viking Range Corporation (Viking) and others. More recently, AGA Rangemaster Group plc (AGA), Bonferraro SpA (Bonferraro), Foshan Shunde Midea Washing Appliances Manufacturing Company, Ltd. (Midea), Merloni Elettrodomestici (Merloni), Samsung Electronics, Inc. (Samsung) and LG Electronics, Inc. (LG) have also entered the domestic market. Table 3.6.1 lists these manufacturers. Figure 3.6.1 illustrates the 2008 market shares for the domestic residential dishwasher market.

[b] AB Electrolux also markets residential dishwashers in much smaller volumes under the Electrolux brand.

Table 3.6.1 Major and Other Dishwasher Manufacturers

Major Manufacturers	Other Manufacturers
Whirlpool	AGA
GE	ASKO
Electrolux	Bonferraro
	BSH Home Appliances
	Dacor
	Equator
	Fagor
	Fisher & Paykel
	Haier
	LG
	Merloni
	Midea
	Miele
	Samsung
	Viking

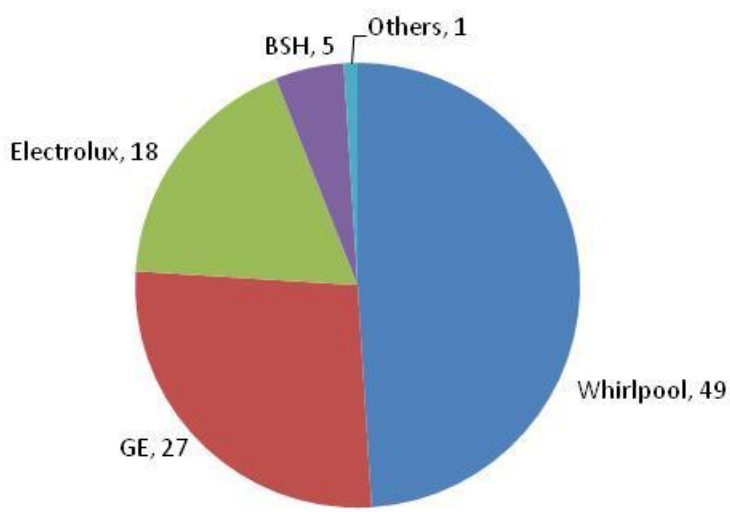

Figure 3.6.1 2008 Market Shares for the Domestic Residential Dishwasher Market[1]

3.6.2 Mergers and Acquisitions

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

According to the January 2010 *Appliance Market Research Report,* three manufacturers comprised 85 percent of the core major appliance market share in 2008. The term “core major appliance” includes dishwashers, dryers, freezers, ranges, refrigerators, and clothes washers. Figure 3.6.2 2008 Core Appliance Market SharesFigure 3.6.2 illustrates the breakdown of 2008 market shares in the core appliance category.

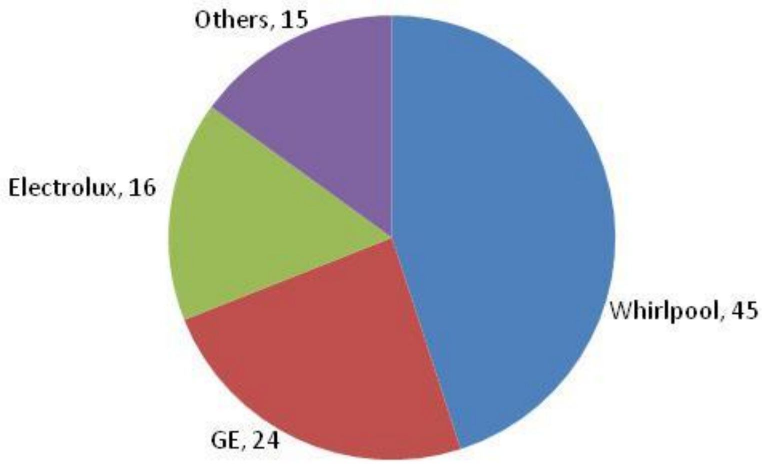

Figure 3.6.2 2008 Core Appliance Market Shares[2]

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

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

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

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

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

Whirlpool and Maytag completed the merger on March 31, 2006. This large merger followed 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. At this time, DOE is not aware of any small manufacturers, defined by the Small Business Association as having 500 employees or fewer,[9] who produce dishwashers and who therefore would be impacted by a minimum efficiency standard.

3.6.4 Distribution Channels

Understanding the distribution channels of dishwashers is an important facet of the market assessment. DOE gathered information regarding the distribution channels for dishwashers from publicly available sources.

The distribution chain for dishwashers, and most residential appliances, 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

2005 Fact Book reports that home improvement stores claim nearly one out of every four dollars spent on appliances.[10]

Home appliance retailers generally obtain products directly from manufacturers. The AHAM *2003 Fact Book* shows that over 93 percent of residential appliances are distributed from the manufacturer directly to a retailer.[11]

3.7 REGULATORY PROGRAMS

The following section details current regulatory programs mandating energy conservation standards for dishwashers. Section 3.7.1 discusses Federal energy conservation standards, and section 3.7.2 reviews standards in Canada that may impact the companies servicing the North American market.

3.7.1 Federal Energy Conservation Standards

Current Federal standards exist for residential dishwashers. The National Appliance Energy Conservation Act of 1987 (NAECA) (42 U.S.C. 6291–6309) amended EPCA to establish prescriptive standards for dishwashers, requiring that they be equipped with an option to dry without heat and further requiring that DOE conduct two cycles of rulemakings to determine if more stringent standards are justified. (42 U.S.C. 6295 (g)(1), (4) and (5)) On May 14, 1991, DOE issued a final rule establishing the first set of performance standards for dishwashers (56 FR 22250); those standards became effective on May 14, 1994. (10 CFR 430.32(f)) DOE initiated a second standards rulemaking for dishwashers by issuing an advance notice of proposed rulemaking (ANOPR) on November 14, 1994. (59 FR 56423) However, as a result of the priority-setting process outlined in 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 suspended the standards rulemaking for dishwashers.

The Energy Independence and Security Act of 2007[c] (EISA 2007) further amended EPCA to establish new energy conservation standards for residential dishwashers manufactured on or after January 1, 2010. (42 U.S.C. 6295(g)(10)(A); 10 CFR 430.32(f)(2)) The current standards established by the EISA 2007 amendments are shown below in Table 3.7.1. The amendments also specify that not later than January 1, 2015, the Secretary shall publish a final rule determining whether to amend the standards for dishwashers manufactured on or after January 1, 2018. (42 U.S.C. 6295(g)(10)(B))

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[c] Pub. L. 110-140 (enacted Dec. 19, 2007).

Table 3.7.1 Current Federal Energy Conservation Standards for Residential Dishwashers

Dishwasher Classification	**Maximum Annual Energy Use** *(kWh/year)*	**Maximum Water Consumption** *(gallons/cycle)*
Compact dishwasher	355	6.5
Standard dishwasher	260	4.5

On July 30, 2010, AHAM and the American Council for an Energy Efficient Economy (ACEEE), additionally representing manufacturers (Whirlpool, GE, Electrolux, LG, BSH Home Appliances (BSH), Alliance Laundry Systems (ALS), Viking Range, Sub-Zero Wolf, Friedrich A/C, U-Line, Samsung, Sharp Electronics, Miele, Heat Controller, AGA Marvel, Brown Stove, Haier, Fagor America, Airwell Group, Arcelik, Fisher & Paykel, Scotsman Ice, Indesit, Kuppersbusch, Kelon, and DeLonghi); energy and environmental advocates (Appliance Standards Awareness Project (ASAP), Natural Resources Defense Council (NRDC), Alliance to Save Energy (ASE), Alliance for Water Efficiency (AWE), Northwest Power and Conservation Council (NPCC), and Northeast Energy Efficiency Partnerships (NEEP)); and consumer groups (Consumer Federation of America (CFA) and the National Consumer Law Center (NCLC)) submitted to DOE a multi-product standards agreement (Consensus Agreement) that addresses negotiated standards for multiple products, including residential dishwashers. Table 3.7.2 shows the negotiated dishwasher standards from the Consensus Agreement, with a proposed 2013 compliance date.

Table 3.7.2 Proposed Consensus Agreement Standards for Residential Dishwashers

Dishwasher Classification	**Maximum Annual Energy Use** *(kWh/year)*	**Maximum Water Consumption** *(gallons/cycle)*
Compact dishwasher	307	5.0
Standard dishwasher	222	3.5

3.7.2 Canadian Energy Conservation Standards

Canada’s Energy Efficiency Regulations (hereafter Regulations) establish energy conservation standards for dishwashers.

Canadian Regulations include maximum energy use requirements and definitions for dishwashers that are identical to the current U.S. Federal standards, setting a maximum annual energy use of 355 kWh/year for standard dishwashers and 260 kWh/year for compact dishwashers. However, the Canadian Regulations do not include any requirements for water consumption.

3.8 VOLUNTARY PROGRAMS

DOE reviewed several voluntary programs promoting energy efficient dishwashers in the United States. Many programs, including the Consortium for Energy Efficiency (CEE), ENERGY STAR, and the Federal Energy Management Program (FEMP), establish voluntary energy conservation standards for these products.

3.8.1 Consortium for Energy Efficiency

The CEE[d] 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.

CEE issues voluntary specifications for residential standard-size and compact dishwashers. Table 3.8.1 presents the dishwasher efficiency specifications, effective August 11, 2009, under its Super-Efficient Home Appliance Initiative (SEHA).

Table 3.8.1 CEE Criteria for Residential Dishwashers

Standard-sized Dishwashers			
Level	**Minimum EF**	**Maximum kWh/yr**	**Maximum gallons/cycle**
Tier 1	0.72	307	5.00
Tier 2	0.75	295	4.25
Compact Dishwashers			
Level	**Minimum EF**	**Maximum kWh/yr**	
Tier 1	1.00	222	3.50

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.[e] 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 should meet or exceed the ENERGY STAR levels. ENERGY STAR specifications exist for several products, including dishwashers.

On August 11, 2009, the current ENERGY STAR residential dishwasher qualifying criteria took effect. The ENERGY STAR program establishes performance requirements for both standard and compact dishwashers. New criteria are set to take effect on January 20, 2012. The current and future ENERGY STAR criteria for residential dishwashers are listed in Table

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[d] For more information, please visit www.cee1.org.

[e] For more information, please visit www.energystar.gov.

3.8.2. The 2012 ENERGY STAR qualifying criteria also include Tier 2 levels for both standard and compact dishwashers, and a possible cleaning performance requirement, but the maximum allowable energy and water use values for that tier have yet to be determined.

Table 3.8.2 ENERGY STAR Qualifying Criteria for Residential Dishwashers

	Current Criteria Levels		**January 20, 2012 Tier 1 Criteria Levels**	
Dishwasher Classification	**Annual Energy Use** *(kWh/year)*	**Water Consumption** *(gallons/cycle)*	**Annual Energy Use** *(kWh/year)*	**Water Consumption** *(gallons/cycle)*
Standard dishwasher	324	5.8	295	4.25
Compact dishwasher	234	4.0	222	3.5

3.8.3 Federal Energy Management Program

DOE's Federal Energy Management Program[f] (FEMP) 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 residential dishwashers.

FEMP issues energy efficiency recommendations for both standard-size and compact residential dishwashers. The FEMP requirements for residential dishwashers are based on the current ENERGY STAR efficiency levels, shown in Table 3.8.2. FEMP estimates a lifetime cost savings of $30 for a standard-size dishwasher just meeting the FEMP requirements (and therefore the ENERGY STAR requirements) compared to a baseline dishwasher.

[f] For more information, please visit www.eere.energy.gov/femp.

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 dishwasher shipment trends and the value of these shipments. Knowledge of such trends will be used during the shipments analysis (chapter 9 of this technical support document (TSD)).

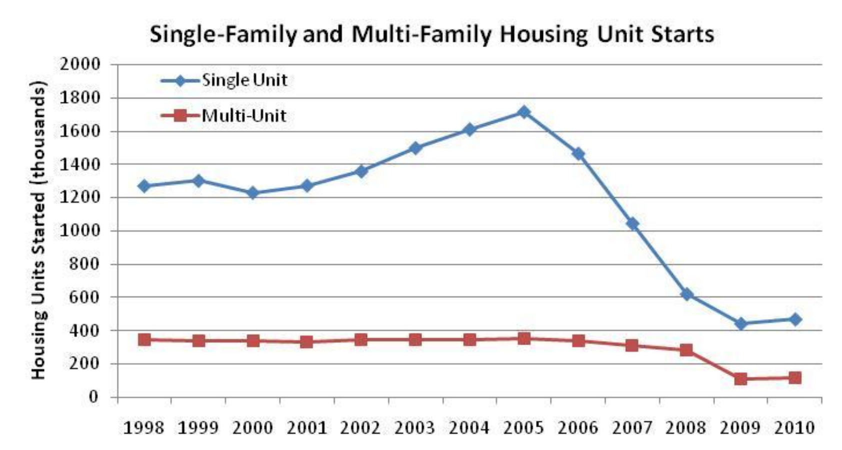
3.9.1 New Home Starts

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 dishwashers, these products are also fixtures in virtually all new homes.

Table 3.9.1 presents the number of new single-family and multi-family housing units started in the United States from 1998 to 2010. Over the 5-year period from 2000–2005, single-family home starts increased 34.8 percent, to 1,716,000 units annually. However, between 2005 and 2010, single-family home starts decreased 72.6 percent, to 471,000 units annually. Multi-family unit starts remained relatively stable during the period 1998–2005 at around 350,000 units annually. Between 2005 and 2010, multi-family units decreased 67.1 percent to 116,000 units annually.

Table 3.9.1 New Privately Owned Single-Family and Multi-Family Housing Unit Starts in the United States from 1998–2010 (Thousands)[12]

Year	Single Unit	Multi-Unit
2010	471	116
2009	445	109
2008	622	284
2007	1046	309
2006	1465	336
2005	1716	353
2004	1611	345
2003	1499	349
2002	1359	346
2001	1273	329
2000	1231	338
1999	1302	339
1998	1271	346



3.9.2 Unit Shipments

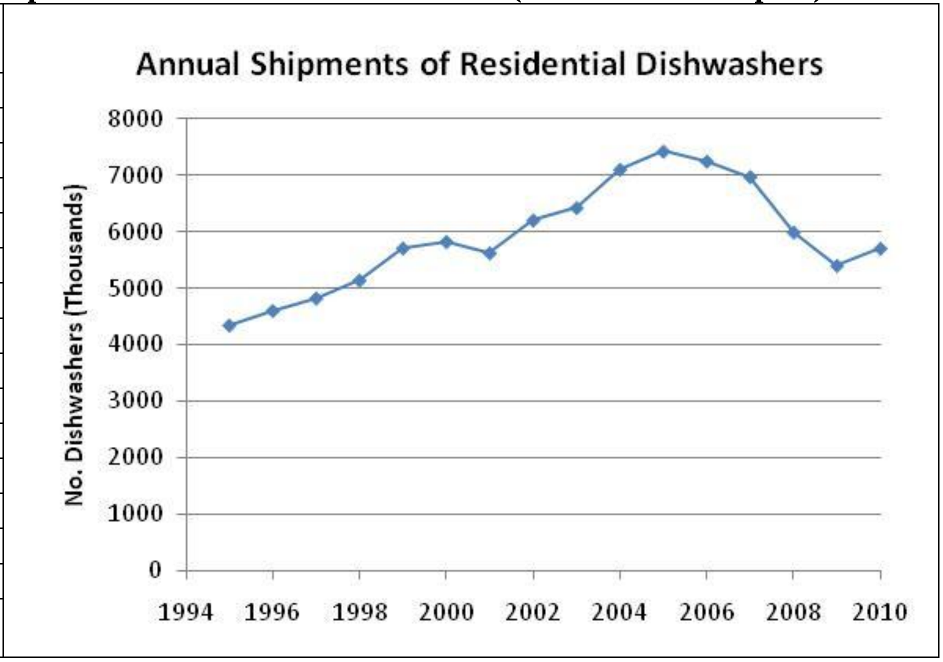
AHAM's *2005 Fact Book* provides annual unit shipments for residential dishwashers from 1995 to 2005. Shipments for 2006 through 2010 were obtained from the January 2011

Appliance Market Research Report's "U.S. Appliance Shipment Statistics January 2011." The two sources contain consistent shipment values for the overlapping years 2000 through 2005. Table 3.9.2 presents the annual shipments of dishwashers for the 14-year period from 1995 to 2010.

Shipments of residential dishwashers peaked in 2005 at around 7.4 million units before declining every year through 2009. The decline in shipments corresponds to the decline in new multi-family and single-family housing starts over the same time period. Dishwasher shipments increased slightly in 2010, corresponding to the small increase in multi-family and single-family housing starts for that year.

Table 3.9.2 Industry Shipments of Residential Dishwashers (Domestic and Import)[13, 14]

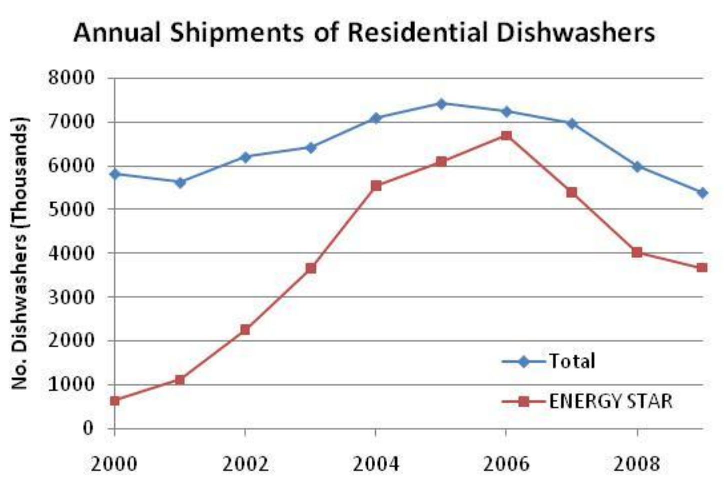
Year	**Shipments** *(Thousands)*
2010	5,708
2009	5,404
2008	5,995
2007	6,977
2006	7,252
2005	7,428
2004	7,106
2003	6,428
2002	6,207
2001	5,627
2000	5,827
1999	5,712
1998	5,144
1997	4,826
1996	4,606
1995	4,346



ENERGY STAR also provides shipments data and market share for qualified residential dishwashers. Table 3.9.3 presents the breakdown of ENERGY STAR versus non-ENERGY STAR shipments for residential dishwashers from 2000 to 2009 from data provided on the ENERGY STAR website.

Table 3.9.3 ENERGY STAR Dishwasher Shipments and Market Share (Domestic and Import)[15]

		Shipments *(Thousands)*	
Year	**% ENERGY STAR**	**Total**	**ENERGY STAR**
2009[a]	68.0%	5,400	3,672
2008	67.2%	5,995	4,030
2007[b]	77.4%	6,977	5,401
2006	92.3%	7,252	6,691
2005	82.0%	7,428	6,092
2004	78.2%	7,106	5,557
2003	56.9%	6,428	3,656
2002	36.4%	6,207	2,262
2001	19.9%	5,627	1,119
2000[c]	10.9%	5,827	632



a) Current ENERGY STAR criteria (effective August 11, 2009)
b) ENERGY STAR criteria (effective January 1, 2007): Standard – EF ≥ 0.65, Compact – EF ≥ 0.88
c) ENERGY STAR criteria: Standard – EF ≥ 0.46, Compact – EF ≥ 0.62

3.9.3 Value of Shipments

Table 3.9.4 provides the value of shipments for the manufacturers in the North American Industry Classification System (NAICS) category of major household appliances (product class code 33522) from 1997 to 2010. The values are based on data from the U.S. Census Bureau's *Current Industrial Reports*[g] (*CIR*) and *Annual Survey of Manufacturers*[h] (*ASM*). This NAICS category includes companies primarily engaged in manufacturing household appliances such as cooking appliances, laundry equipment, refrigerators, upright and chest freezers, dishwashers, water heaters, and garbage disposal units. The U.S. Census Bureau reports all shipment values in nominal dollars, *i.e.*, 2010 data are expressed in 2010 dollars and 2009 data are expressed in 2009 dollars. Using the Gross Domestic Product Implicit Price Deflator (GDPIPD) published by the U.S. Bureau of Economic Analysis,[i] DOE converted each year's value of shipments to 2010 dollars.

[g] Available online at www.census.gov/manufacturing/cir/index.html
[h] Available online at www.census.gov/manufacturing/asm/index.html
[i] Available online at www.bea.gov/national/nipaweb/SelectTable.asp

Table 3.9.4 Annual Shipment Value of Major Household Appliances[16, 17, 18, 19, 20]

	Annual Shipment Value *($ millions)*	
Year	**Nominal Dollars**	**2010 Dollars**
2010	18,823.6	18,823.6
2009	18,253.8	18,427.7
2008	17,808.0	18,142.5
2007	19,575.0	20,378.5
2006	20,255.0	21,707.0
2005	20,730.0	22,939.6
2004	19,747.4	22,581.7
2003	18,721.7	22,016.2
2002	17,645.9	21,197.6
2001	17,295.5	21,113.1
2000	17,836.1	22,265.0
1999	17,479.6	22,292.6
1998	16,713.9	21,629.3
1997	15,487.1	20,268.3

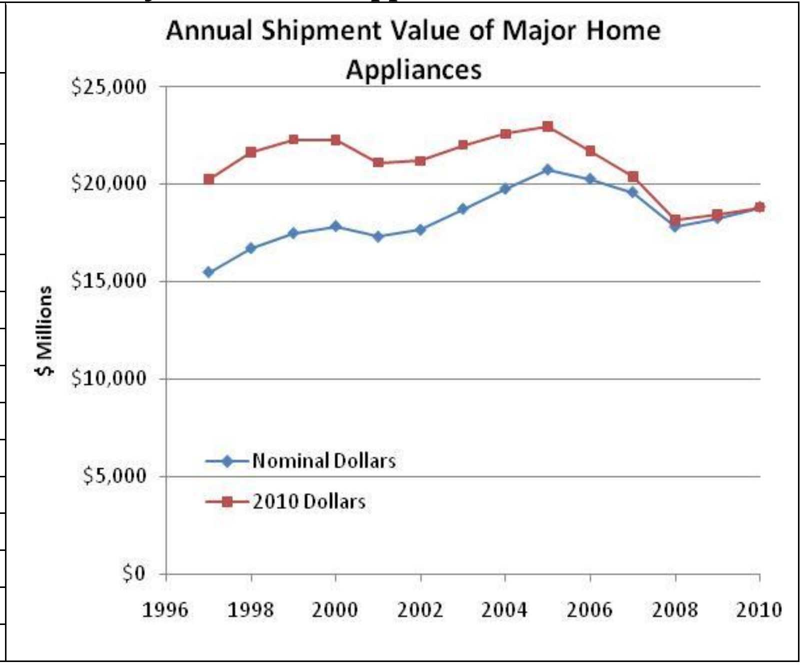
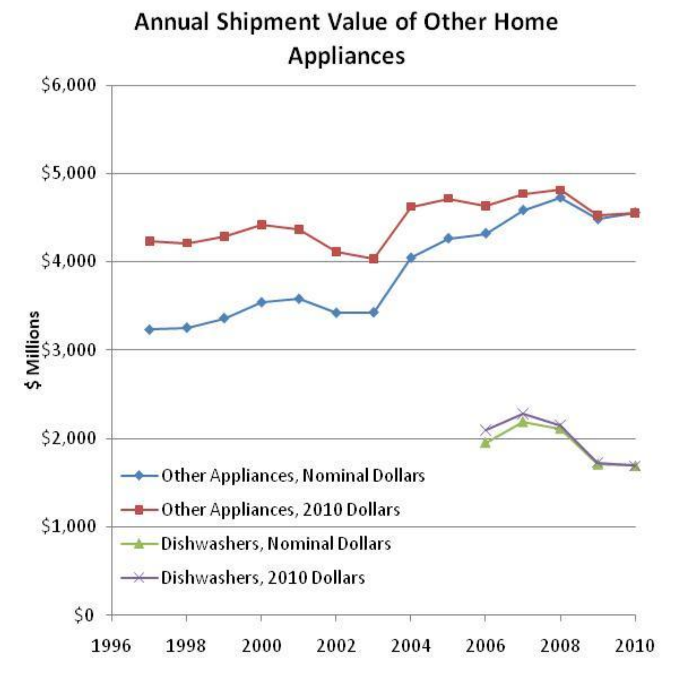


Table 3.9.5 provides the annual shipment value for the NAICS product class for "Other Household Appliances" (product class code 335228), which includes dishwashers, food waste disposal units, garbage disposal units, water heaters, and trash compactors, from 1997 to 2010 based upon data from the U.S. Census Bureau's *CIR* and *ASM*. Also included in Table 3.9.5 are dishwasher shipment values from 2006 to 2010—the only years that dishwashers are specifically broken out in the *CIR*. Over these 4 years, dishwashers represented slightly less than half of the total annual shipments value for the Other Household Appliances product category. The U.S. Census Bureau shipment values are expressed in nominal dollars. DOE used the GDPIPD to convert each year's value of shipments to 2010 dollars.

Table 3.9.5 Annual Shipment Value of Other Major Household Appliances[21, 22, 23, 24, 25, 26, 27, 28]

	Annual Shipment Value *($ millions)*			
	Other Home Appliances		Dishwashers	
Year	Nominal Dollars	2010 Dollars	Nominal Dollars	2010 Dollars
2010	4,553.1	4,553.1	1,690.4	1,690.4
2009	4,479.9	4,522.6	1,709.5	1,725.8
2008	4,722.9	4,811.6	2,114.2	2,153.9
2007	4,581.7	4,769.8	2,189.0	2,278.9
2006	4,319.4	4,629.0	1,954.4	2,094.5
2005	4,263.5	4,717.9	N/A	N/A
2004	4,042.9	4,623.2	N/A	N/A
2003	3,428.1	4,031.4	N/A	N/A
2002	3,422.7	4,111.6	N/A	N/A
2001	3,579.7	4,369.8	N/A	N/A
2000	3,540.7	4,419.9	N/A	N/A
1999	3,362.3	4,288.1	N/A	N/A
1998	3,255.1	4,212.4	N/A	N/A
1997	3,232.1	4,229.9	N/A	N/A



According to data presented in the AHAM *2003 Fact Book*, many old appliances are still being used after consumers purchase new units of same product. Table 3.9.6 presents the various methods by which consumers dispose of their older dishwashers.

Table 3.9.6 Disposition of Previous Dishwasher[29]

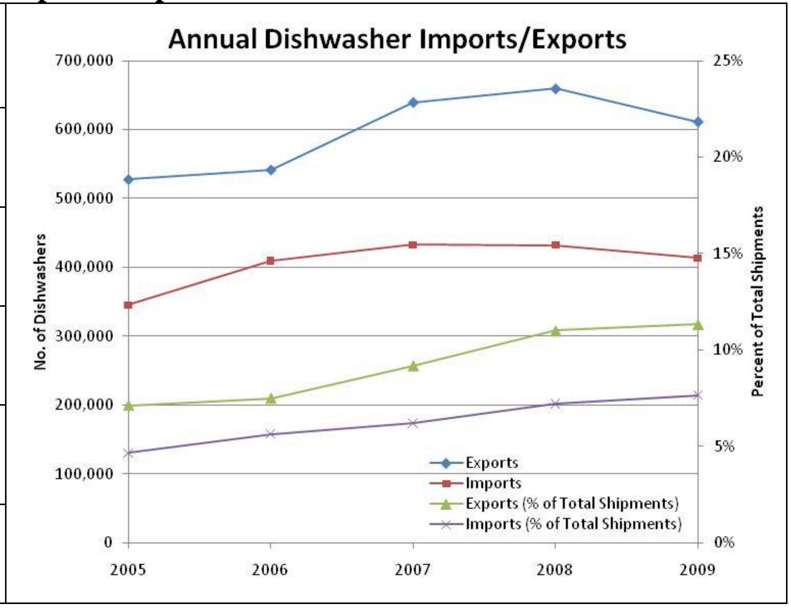
Product	Kept It	Left with Previous Home	Sold / Gave Away	Recycling Facility	Left at Curb for Disposal	Retailer Took Away
Dishwashers	4%	37%	15%	14%	11%	20%

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, which includes year-to-date annual summaries. Table 3.9.7 shows selected import/export data from AHAM's *Import/Export Trade Reports* for December 2008–2009 as well as AHAM's *Final 2006 Major Appliance Trade Report (Imports & Exports)*. Over the 5-year period of 2005 through 2009, imports and exports both rose as a share of total shipments. Overall, the United States imports more dishwashers than it exports.

Table 3.9.7 Annual Dishwasher Imports/Exports[30, 31, 32]

Year	Imports *(% of total shipments)*	Exports *(% of total shipments)*
2009	611,743 *(11.3%)*	413,308 *(7.7%)*
2008	659,645 *(11.0%)*	432,332 *(7.2%)*
2007	639,866 *(9.2%)*	432,610 *(6.2%)*
2006	542,012 *(7.5%)*	409,817 *(5.7%)*
2005	527,983 *(7.1%)*	345,125 *(4.6%)*

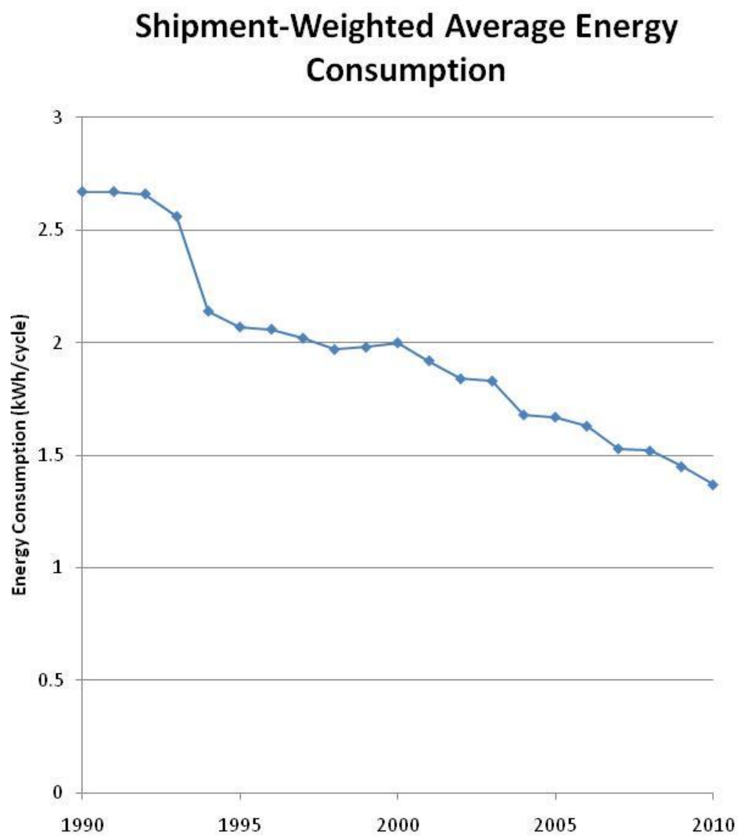


3.10 HISTORICAL EFFICIENCIES

The average efficiency of new dishwashers has increased greatly since 1990. Table 3.10.1 shows the shipment-weighted average energy consumption per cycle. Over the period from 1990 to 2010, the average energy consumption per cycle decreased by over 48 percent.

Table 3.10.1 Annual Shipment-Weighted Per-Cycle Dishwasher Energy Consumption[33, 34]

Year	Energy Consumption *(kWh/cycle)*	% Change vs. 1990
2010[a]	1.37	-48.7%
2009	1.45	-45.7%
2008	1.52	-43.1%
2007	1.53	-39.0%
2006	1.63	-37.5%
2005	1.67	-37.1%
2004	1.68	-37.1%
2003	1.83	-31.5%
2002	1.84	-31.1%
2001	1.92	-28.1%
2000	2.00	-25.1%
1999	1.98	-25.8%
1998	1.97	-26.2%
1997	2.02	-24.3%
1996	2.06	-22.8%
1995	2.07	-22.5%
1994[b]	2.14	-19.9%
1993	2.56	-4.1%
1992	2.66	-0.4%
1991	2.67	0.0%
1990	2.67	-



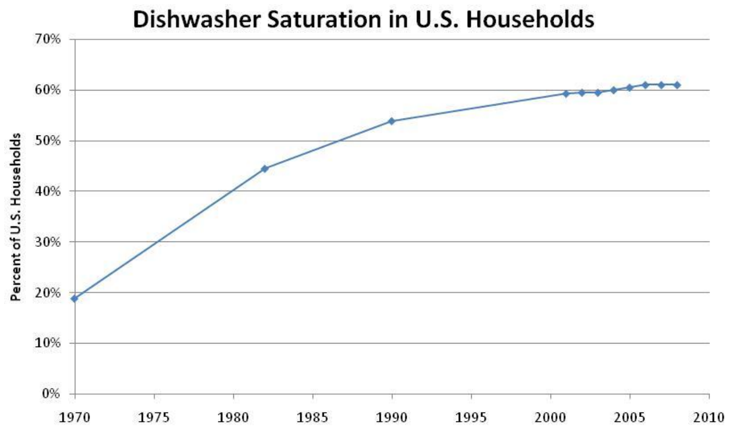
a) Current DOE energy conservation standards for annual energy use took effect on January 1, 2010.
b) DOE energy conservation standards for EF took effect on May 14, 1994.

3.11 MARKET SATURATION

AHAM's *2005 Fact Book* and the January 2010 *Appliance Market Research Report* present the market saturation for dishwashers. The market saturation of dishwashers has more than tripled since 1970. However, from 2001 through 2008 the market saturation only increased by 1.7 percent. For the 3 years from 2006 through 2008, the market saturation remained constant at 61 percent. Table 3.11.1 presents the percentage of U.S. households with dishwashers.

Table 3.11.1 Percentage of U.S. Households with Dishwashers[35,36]

Year	% of U.S. Households
2008	61.0
2007	61.0
2006	61.0
2005	60.5
2004	60.0
2003	59.5
2002	59.5
2001	59.3
1990	53.9
1982	44.5
1970	18.9



3.12 PRODUCT RETAIL PRICES

Table 3.12.1 presents the average retail prices (in nominal dollars) for dishwashers and the consumer price index (CPI) for each year (1982–1984 = 100). While prices for dishwashers rose from 1980 to 2002, they dropped dramatically from 2002 to 2005 resulting in a net decrease in average retail price between 1980 and 2005. The decrease in prices is even more significant when factoring in the 137 percent increase in the CPI over the same time period.

Table 3.12.1 Average Dishwasher Retail Prices[37]

	Average Retail Prices *(Nominal $)*				**Percent Change**
	1980	**1994**	**2002**	**2005**	**1980–2005**
Dishwashers	353	395	400	284	-19.5%
Consumer Price Index[a]	*82.4*	*148.2*	*179.9*	*195.3*	*137.0%*

a) U.S. Department of Labor, Bureau of Labor Statistics, Consumer *Price Index: U.S. City Average*. 1982–1984 = 100.

DOE conducted an in-depth search of consumer retail prices for dishwashers by gathering consumer prices from three major appliance retailers: Sears, Home Depot, and AJMadison.com. The Sears and Home Depot websites were used for this search. DOE identified a total of 235 standard-size models, which encompassed 28 different brands. For models that were available in multiple colors, or at multiple retailers, DOE used the least expensive full price, not including retail discounts. DOE used the California Energy Commission (CEC)[j] and ENERGY STAR[k] product databases to match the rated energy and water consumption data with each dishwasher model.

Figure 3.12.1 and Figure 3.12.2 summarize the data collected by DOE. The figures show that retail price is loosely related to efficiency, more so for energy use than for water consumption. The consumer retail prices for standard-size dishwashers ranged from $239 to $2,369, with a (non-shipment-weighted) average of $883. Dishwashers are available with annual energy use ratings between 300 and 324 kWh/year at price-points ranging from $250 to $2250. However, the baseline retail price generally increases for dishwashers as annual energy use decreases below 300 kWh/year. The data comparing price with rated water consumption do not show such a clear trend. However, in general, the data show that retail price rises slightly for units with lower water use ratings.

[j] CEC appliance efficiency database available online at: www.energy.ca.gov/appliances/database/.
[k] ENERGY STAR database available online at:
www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=DW

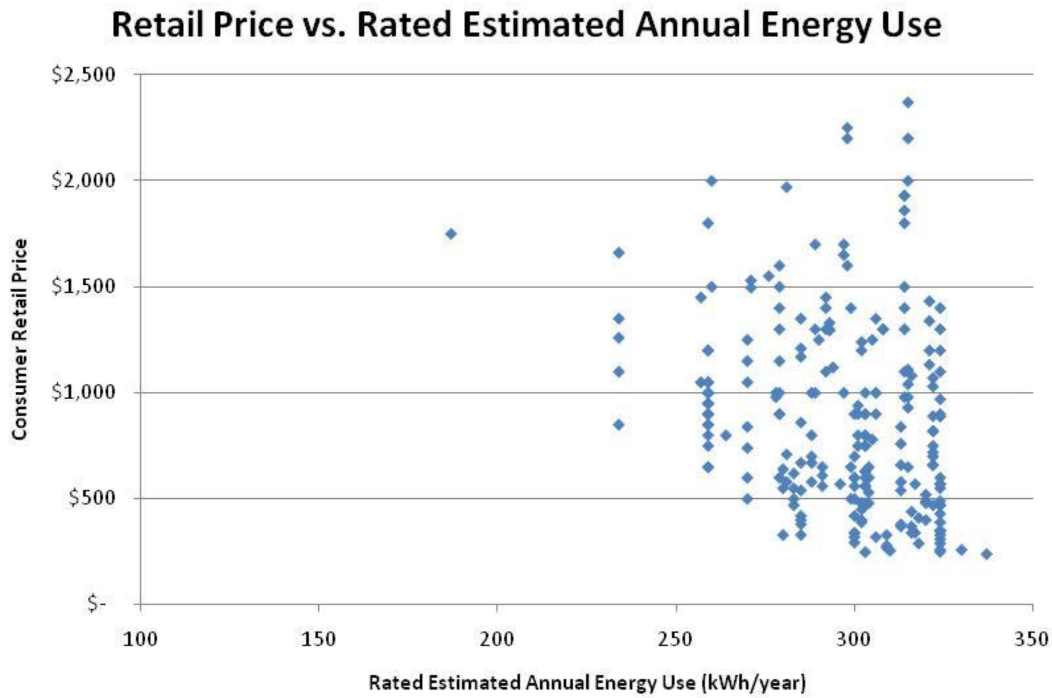


Figure 3.12.1 Standard-Size Residential Dishwasher Retail Price as a Function of Annual Energy Use

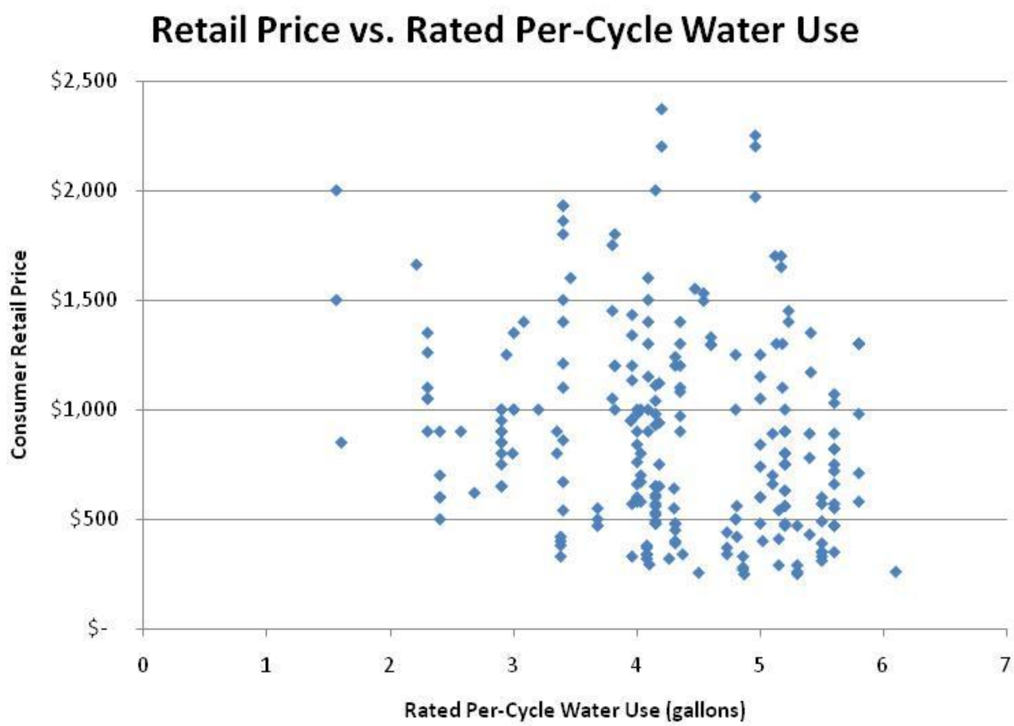


Figure 3.12.2 Standard-Size Residential Dishwasher Retail Price as a Function of Water Consumption

3.13 INDUSTRY COST STRUCTURE

DOE developed the household appliance industry cost structure from publicly available information from the *ASM* and Economic Census, (Table 3.13.1 and Table 3.13.3) and the U.S. Securities and Exchange Commission (SEC) 10-K reports filed by publicly owned manufacturers (summarized in Table 3.13.5). Table 3.13.1 presents the major appliance manufacturing industry (NAICS code 33522) employment levels and earnings from 1997 through 2009. The statistics illustrate a steady decline in the number of production and non-production workers in the industry since 2000.

DOE converted the payroll data to constant 2010 dollars using the GDPIPD published by the U.S. Bureau of Economic Analysis.[1] Table 3.13.1 shows that as industry employment levels decline, the industry payroll in constant 2010 dollars also decreases. The percent decrease in total industry employees tracks closely with the percent decrease in payroll for all employees.

Table 3.13.1 Major Appliance Manufacturing Industry Employment and Earnings[38]

Year	Production Workers	All Employees	Payroll for All Employees *(2010 $ Mil)*
2009	32,875	37,905	1,525.7
2008	39,163	44,717	1,822.1
2007	45,370	52,045	2,038.7
2006	49,360	56,174	2,298.0
2005	54,083	62,877	2,427.9
2004	57,660	68,213	2,701.5
2003	58,289	68,593	2,738.0
2002	59,234	70,013	2,867.8
2001	60,669	70,938	2,951.1
2000	64,417	75,055	3,163.0
1999	64,066	73,884	3,106.4
1998	62,822	73,113	3,036.7
1997	59,697	69,727	2,838.4

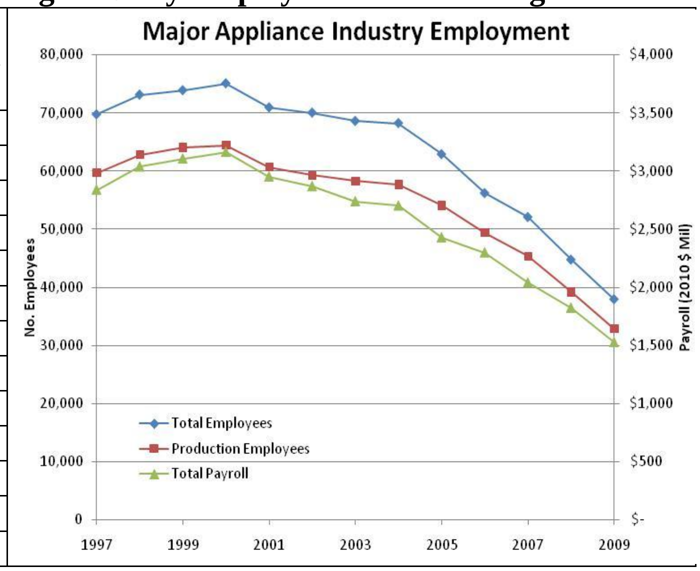


Table 3.13.2 presents the employments levels and payroll for the "Other Major Home Appliances" portion of the major appliance industry. As shown in Table 3.9.5, dishwashers represent slightly less than half of the total shipments value for the Other Major Home Appliance industry. Statistics for both employment levels and payroll show a slight decrease from 1997 to 2009. The decrease is of a much smaller magnitude than for the major appliance industry overall.

[1] Available online at www.bea.gov/national/nipaweb/SelectTable.asp

Table 3.13.2 Other Major Home Appliance Industry Employment and Earnings[39]

Year	Production Workers	All Employees	Payroll for All Employees *(2010 $ Mil)*
2009	7,651	9,516	408.7
2008	9,103	11,113	471.7
2007	9,792	11,516	490.5
2006	10,281	11,974	520.7
2005	10,179	12,360	535.7
2004	10,304	12,672	549.2
2003	10,519	12,819	549.9
2002	10,118	12,671	579.3
2001	10,392	12,770	576.6
2000	11,775	14,088	592.5
1999	11,081	13,166	577.1
1998	11,195	13,215	544.8
1997	10,881	12,848	535.8

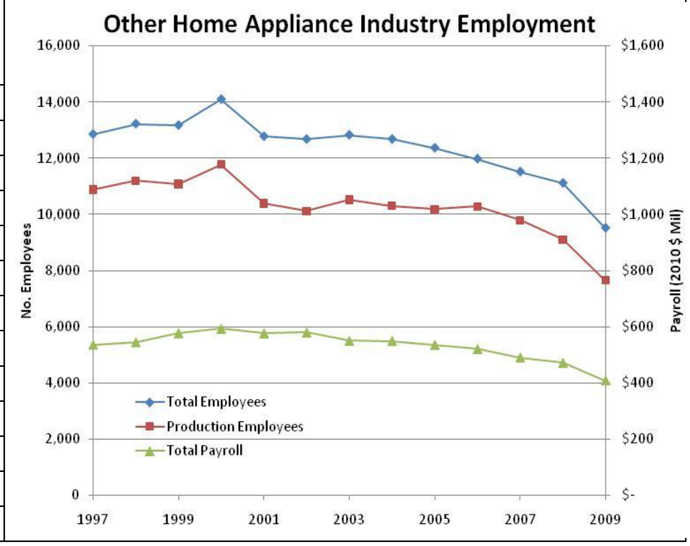


Table 3.13.3 presents the costs of materials and industry payroll as a percentage of value of shipments from 1997 to 2009 for the major appliance industry. The cost of materials as a percentage of value of shipments has slowly risen over the 13-year period, with small fluctuations. DOE notes that fluctuations in raw material costs are common from year to year. The cost of payroll for both production and non-production workers as a percentage of value of shipments has declined since 2000.

Table 3.13.3 Major Appliance Manufacturing Industry Materials and Wages Cost[40]

	Cost as a Percentage of Value of Shipments *(%)*		
Year	**Materials**	**Payroll for Production Workers**	**Payroll for All Other Employees**
2009	55.0%	7.8%	2.4%
2008	59.4%	7.8%	2.2%
2007	58.4%	8.0%	2.0%
2006	58.7%	8.5%	2.1%
2005	57.4%	8.3%	2.3%
2004	58.3%	9.3%	2.7%
2003	56.8%	9.5%	2.9%
2002	57.0%	10.2%	3.3%
2001	58.5%	10.7%	3.3%
2000	57.3%	10.8%	3.4%
1999	55.7%	10.7%	3.2%
1998	55.6%	10.8%	3.2%
1997	53.4%	10.9%	3.1%

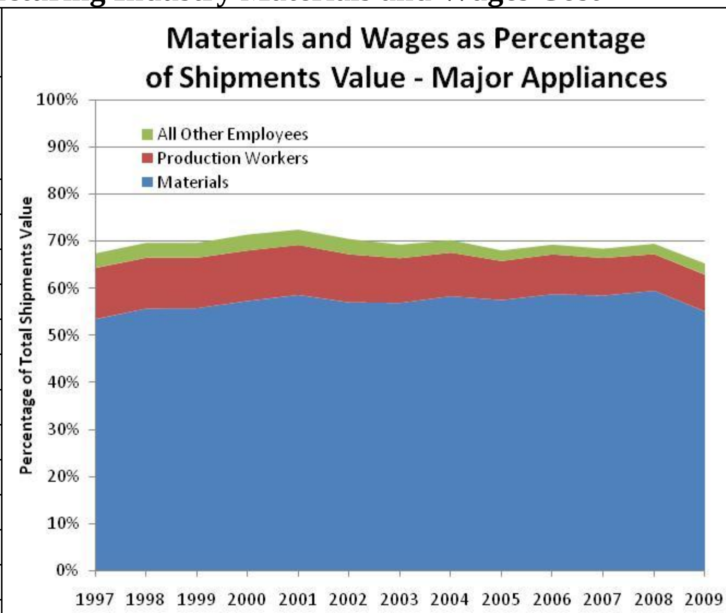
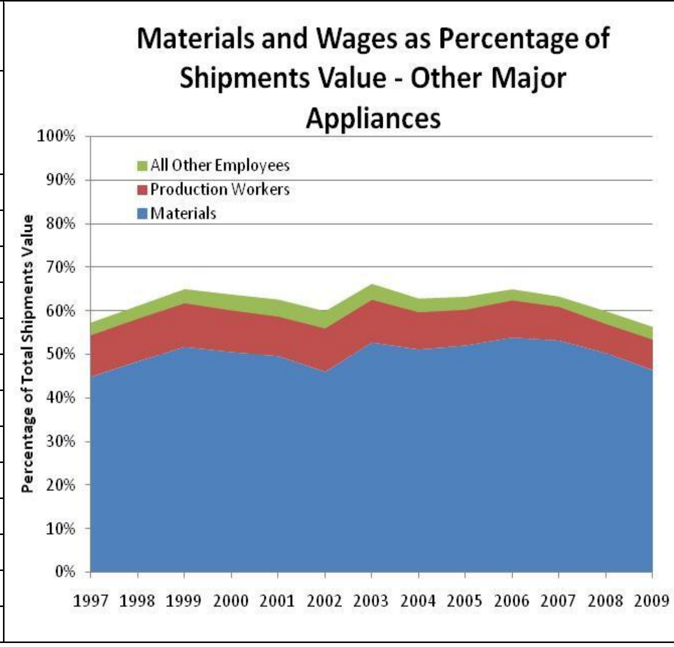


Table 3.13.4 shows the cost of materials and industry payroll as a percentage of value of shipments for the other major appliance industry from 1997 to 2009. Material prices as a percentage of value of shipments have remained relatively constant over the 13-year period, with fluctuations from year-to-year. The cost of payroll for production and other employees has remained relatively constant over the 13-year period, with fluctuations from year-to-year. DOE notes that, overall, wages and cost of materials combined represent a smaller percentage of the total shipments value for the other major appliance industry than for the major appliance industry as a whole.

Table 3.13.4 Other Major Appliance Industry Materials and Wages Cost[41]

	Cost as a Percentage of Value of Shipments *(%)*		
Year	**Materials**	**Payroll for Production Workers**	**Payroll for All Other Employees**
2009	46.3%	7.2%	2.9%
2008	50.2%	6.9%	2.9%
2007	53.1%	7.9%	2.4%
2006	53.8%[a]	8.7%	2.5%
2005	52.0%	8.4%	3.0%
2004	51.0%	8.7%	3.1%
2003	52.7%	10.0%	3.7%
2002	45.9%	10.1%	4.0%
2001	49.5%	9.3%	3.9%
2000	50.4%	9.8%	3.6%
1999	51.6%	10.2%	3.3%
1998	48.3%	10.0%	3.0%
1997	44.7%	9.8%	2.9%



a) Cost of Materials data not available for 2006; the average value from 2005 and 2007 was used as an estimate.

Table 3.13.5 through Table 3.13.7 present the industry financial parameters derived from publicly available sources of financial data including SEC 10-K reports for U.S.-based home appliance manufacturers whose range of products includes residential dishwashers. DOE averaged the financial data from 2003–2010 for each manufacturer and weighted this by their respective market share to obtain an industry average. Each financial statement entry is presented as a percentage of total revenues.

Table 3.13.5 Industry Financials from Income Statement, Average 2003–2010

Income Statement Entry	**Percent of Revenues**
Cost of sales	80.6%
Selling, general and administrative	13.3%
Research and development	2.3%
Depreciation*	3.1%
Earnings before interest and taxes	5.7%

*Depreciation appears on both the income statement and cash flow statement.

Table 3.13.6 Industry Financials from Cash Flow Statement, Average 2003–2010

Cash Flow Statement Entry	**Percent of Revenues**
Capital expenditure	3.2%

Table 3.13.7 Industry Financials from Balance Sheet, Average 2003–2010

Financial Statement Entry	**Percent of Revenues**
Net plant, property and equipment	16.7%
Working capital	7.0%

A detailed financial analysis is presented in the manufacturer impact analysis (chapter 12 of the final rule TSD). This analysis identifies key financial inputs including cost of capital, working capital, depreciation, capital expenditures, etc.

3.14 INVENTORY LEVELS AND CAPACITY UTILIZATION RATES

Table 3.14.1 and Table 3.14.2 show the year-end inventory for the major appliance manufacturing and other major appliance manufacturing industries, according to the *ASM*. Both in dollars and as a percentage of value of shipments, the end-of-year inventory for the major appliance industry steadily declined between 1997 and 2005. Inventories increased as a percentage of the total value of shipments beginning in 2006, corresponding to the deterioration of the U.S. economy during that period. Other major appliance inventories do not show these same trends. The value of the end-of-year inventories remained relatively steady over the 13-year period, as did the inventory as a percentage of total shipment values, with fluctuations from year-to-year.

Table 3.14.1 Major Appliance Manufacturing Industry Inventory Levels[42]

Year	End-of-Year Inventory *(2010 $ Mil)*	EOY Inventory as % of Shipments Value
2009	1,338.6	7.3%
2008	1,412.5	7.8%
2007	1,536.9	7.5%
2006	1,351.0	6.2%
2005	1,388.0	6.1%
2004	1,413.4	6.3%
2003	1,395.8	6.3%
2002	1,500.6	7.1%
2001	1,663.7	7.9%
2000	1,890.7	8.5%
1999	1,901.3	8.5%
1998	1,939.1	9.0%
1997	1,866.5	9.2%

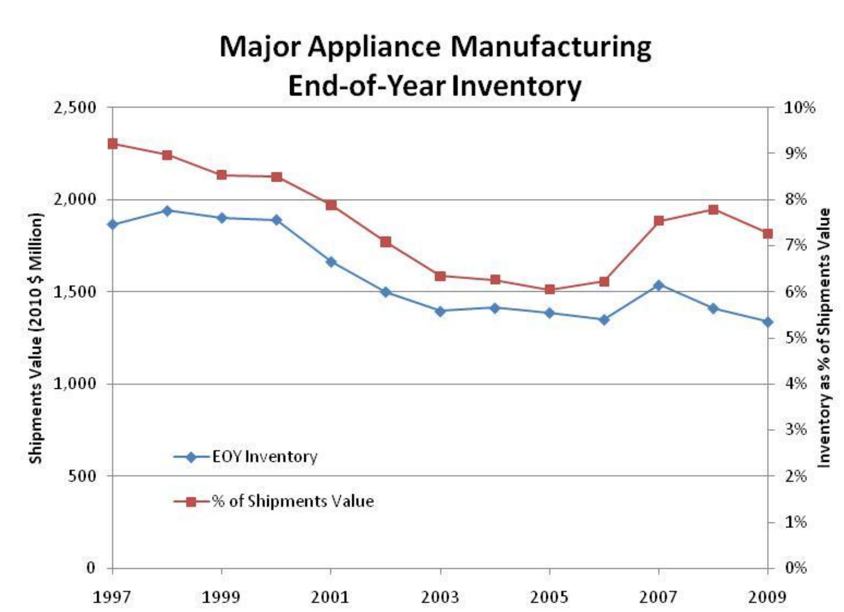
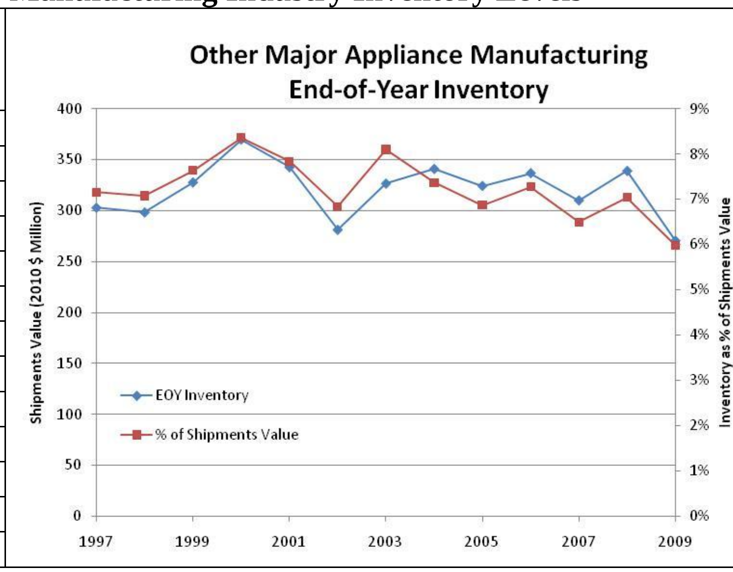


Table 3.14.2 Other Major Appliance Manufacturing Industry Inventory Levels[43]

Year	End-of-Year Inventory *(2010 $ Mil)*	EOY Inventory as % of Shipments Value
2009	270.6	6.0%
2008	338.7	7.0%
2007	309.9	6.5%
2006	336.6	7.3%
2005	324.1	6.9%
2004	340.7	7.4%
2003	326.3	8.1%
2002	281.1	6.8%
2001	342.4	7.8%
2000	369.5	8.4%
1999	327.5	7.6%
1998	298.2	7.1%
1997	302.7	7.2%

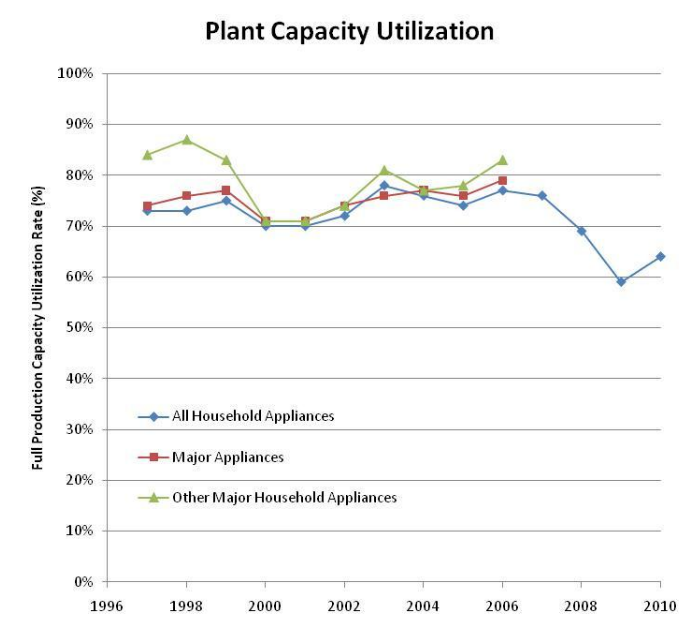


DOE obtained full production capacity utilization rates from the U.S. Census Bureau's *Survey of Plant Capacity* from 1997–2006. After 2006, the Census Bureau discontinued this survey, and began a new *Quarterly Survey of Plant Capacity Utilization*. However, this survey does not break down the utilization data beyond the "all household appliances" industry. Table 3.14.3 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* reports, 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 all household appliances shows fairly steady utilization between 70 and 78 percent from 1997 through 2007, with a significant decrease to less than 60 percent from 2007 through 2009. However, in 2010 the utilization rate rebounded slightly from its low in 2009. Data for major appliance and "other major household appliance" manufacturers tracks closely with the overall household appliance data from 1997 through 2006.

Table 3.14.3 Full Production Capacity Utilization Rates[44, 45]

	Plant Capacity Utilization Rates *(%)*		
Year	**All Household Appliances**	**Major Appliances[a]**	**Other Major Home Appliances[a]**
2010	67%	N/A	N/A
2009	58%	N/A	N/A
2008	59%	N/A	N/A
2007	76%	N/A	N/A
2006	77%	79%	83%
2005	74%	76%	78%
2004	76%	77%	77%
2003	78%	76%	81%
2002	72%	74%	74%
2001	70%	71%	71%
2000	70%	71%	71%
1999	75%	77%	83%
1998	73%	76%	87%
1997	73%	74%	84%



a) Data unavailable after 2006.

3.15 TECHNOLOGY ASSESSMENT

This section provides a technology assessment for residential dishwashers. Contained in this technology assessment are details about product characteristics and operation (section 3.15.1), an examination of possible technological improvements (section 3.15.2), and a characterization of the product efficiency levels currently commercially available (section 3.15.3).

3.15.1 Dishwasher Operations and Components

Residential dishwashers are a product designed to clean dishes, utensils, and cookware by using a solution of detergent and heated water. Dishwashers spray this solution from rotating spray arms onto the dishes in order to clean and sterilize them. Dishwashers use electricity to power an electric motor for the pump system that circulates the wash solution, a heating element which heats the wash solution and assists in drying the dishes, and an optional drain pump. In addition, dishwasher controls consume some electricity and some dishwashers contain a drying fan which circulates air through the dishwasher to aid dish drying. Although almost all dishwashers are capable of heating water with their internal heating element, dishwashers in the United States are typically connected to the hot water line to supply hot water. Water is automatically fed to the dishwasher through an electrically-operated water valve connected to the hot water pipe. The dishes, utensils, and cookware are washed, rinsed and dried within a tub that is inside the dishwasher cabinet.

Dishwashers are traditionally front-loading appliances. The door on the front of the cabinet cantilevers down, and the washer racks slide out on railings for loading and unloading. When the dishwasher is loaded and the washer racks are slid into the dishwasher cabinet, the cabinet door is closed, sealing the tub, and a door switch indicates that the door latch has sealed the cabinet door. The dishwasher controls, which may be electromechanical or electronic, can then begin the wash cycle.

The wash cycle begins when the water fill valve fills the dishwasher tub until the control timer indicates a complete fill, or the dishwasher float switch indicates that the tub is full, or a water meter indicates a sufficient amount of water has entered the tub. The main pump, which provides pressurized fluid to the dishwasher spray arms, is attached to the sump of the tub, where water accumulates. The pump, which uses a rotating impeller to pressurize the fluid and deliver it to the spray arms, is connected directly to the electric motor, or connected by a belt or other form of transmission. The heating element can be part of the sump or installed above it. The heating element ensures the water is heated to an adequate temperature for cleaning. The detergent is released from an electrically controlled detergent container which is filled with detergent prior to initiating the dishwashing cycle.

Dishwashers can be further segregated, depending on whether they feature one or two pumps. On a one-pump model, the main pump not only pressurizes the wash and rinse system, but it can also be used to drain the wash fluid, either by reversing the pump direction (forcing the fluid out the drain), or by using a diverting valve located on the pump output line. Dishwashers with two pumps use one pump optimized for cleaning and rinsing procedures and a second pump optimized for draining. After each drain cycle (until the cleaning cycle ends), the tub is refilled with water for rinse or wash operations. Dishwashers may drain and refill the tub multiple times during the dishwashing cycle as the washing and rinsing water becomes soiled. In some dishwashers this process is controlled by a timer, while other dishwashers use sensors and electronic controls to determine when to change the water, the amount of water for each fill, water temperatures in each cycle, and other variables.

The heating element is activated to heat the dishwasher cabinet and speed up drying once the dishwasher completes the rinse and drain cycles. Dishwashers with an additional drying fan and air heater utilize these devices during the drying phase of the wash cycle.

Some dishwashers use separate drawers for each washing rack, instead of one large tub with two or more racks running on extensible rails. These multi-drawer dishwashers are essentially two small dishwashers stacked on top of each other. This two-drawer system allows users to run the dishwasher with smaller loads without wasting the water or energy a full-size dishwasher would use on a half-empty load.

3.15.2 Dishwasher Technology Options

For dishwashers, DOE will consider technologies identified in the following three sources: (1) DOE's ANOPR initiating a standards rulemaking for residential dishwashers, dehumidifiers, cooking products, and commercial clothes washers published on November 15, 2007 (72 FR 64432); (2) information provided by trade publications; and (3) design data identified in manufacturer product offerings.

The technology options for dishwashers are listed in Table 3.15.1. They are changes that can be incorporated into the design of a dishwasher to improve its efficiency.

Table 3.15.1 Technology Options for Residential Dishwashers

1. Condenser drying
2. Control strategies
3. Fan/jet drying
4. Flow-through heating
5. Improved fill control
6. Improved food filter
7. Improved motor efficiency
8. Improved spray-arm geometry
9. Increased insulation
10. Low-standby-loss electronic controls
11. Microprocessor controls and fuzzy logic, including adaptive or soil-sensing controls
12. Modified sump geometry, with and without dual pumps
13. Reduced inlet-water temperature
14. Supercritical carbon dioxide washing
15. Ultrasonic washing
16. Variable washing pressures and flow rates

Condenser drying

This technology reduces the amount of energy required to dry the dishes at the end of the wash cycle. Instead of using an exposed electric heating element to dry the dishes, hot rinse water is used to heat the dishes to a high temperature. Subsequently, room air is admitted into the dishwasher. Simple convection then pulls cooler, less moist air into the dishwasher from the bottom of the cabinet and discharges warm, moist air out of the top of the cabinet. Some designs do not allow outside air into the dishwasher and pull cool air over the exterior cabinet surface instead. As the warm, moist air inside the dishwasher encounters the cavity walls (via natural convection), the water condenses on the wall surface and runs into the sump. Most European installations connect the dishwasher to the cold water line. A reservoir of cold water can thus be maintained on the outside of the stainless tub, providing a chilled surface on which the moisture can condense. U.S. condensing systems are less effective because the condensing surface is not as cool.

Control strategies

Effective dishwashing requires water, heat, mechanical action (spraying of water), time, and detergent. Manufacturers may adjust the controls of a dishwasher to limit the amount of water used, or the set-point temperature of the wash or rinse water. This improves efficiency by decreasing the amount of energy associated with water heating. To help compensate for the negative impact on cleaning performance associated with decreasing water use and water temperature, manufacturers will typically increase the cycle time. This allows more time for the smaller volume of water to be circulated within the cabinet, helping to maintain wash performance.

Fan/jet drying

To reduce drying times, some dishwasher designs use a fan to circulate air and to accelerate the drying process outlined in the condenser drying section above. Fans may be installed in the dishwasher door or in the cabinet itself, with the condensing water being diverted back into the sump. Convection fan systems are found on some of the higher efficiency dishwashers currently available on the U.S. market.

Flow-through heating

As discussed in section 3.15.1, dishwashers use either an exposed tubular or a flow-through supplemental water heating element to bring water inside the dishwasher up to operating temperature. Water is heated before being pumped and distributed to the spray arms. Typically, dishwashers with exposed tubular heating elements require more standing water than dishwashers with flow-through heaters. Flow-through heaters consist of a metallic flow tube around which an electrical tubular resistance heater is wrapped. The flow-through heater usually connects the sump to the main pump and hence forms an integral part of the water circuit. The volume of water required to fill a flow-through element is typically much lower than the volume required to at least partially submerge a tubular supplemental heating element. The potential water and energy savings depend upon the configuration of the sump and type of supplemental water heating element.

Improved fill control

Modifying the fill control to admit a lower volume of water can reduce hot water consumption and energy use. In models that use electro-mechanical controls, this could be accomplished by reducing the safety factor employed by manufacturers to ensure proper fill volumes. Safety factors, which result in overfill for some consumers, are applied to the volume of the sump region and also to the timer-activated water fill to ensure enough water for proper pump action and cleaning. The use of more accurate electronic timers would maintain a tighter tolerance on the fill time period.

Dishwashers with electro-mechanical controls also employ an overfill factor to account for varying water pressures. Water flow rates through valves vary with water pressure, so the use of mechanical timer controls could cause a variation in the quantity of hot water delivered. Therefore, an additional overfill factor of 10 or 15 percent is traditionally used to compensate for the range of water pressures existing in the United States The use of pressure-activated water volume sensors could be used to control water fill rather than a mechanical timer to reduce overfills.

Dishwashers may alternatively use a float switch mounted in the sump to terminate the filling process. The float switch is an electro-mechanical switch activated by the rising water level in the sump. Once the sump has been filled to the appropriate level, the float triggers the switch, terminating the fill. Because the float switch directly measures the water level, it can enable a high degree of fill control. However, simple float switches can only measure one fill level, which may be inadequate for washers with very high efficiency targets.

The most sophisticated water fill control option is to incorporate a water meter into the dishwasher. Such a device allows the controller to measure exactly how much water has been added and allows the washer to tailor its water input precisely to the needs of each individual wash or rinse cycle. By metering the water precisely, this approach gives the dishwasher controller greater flexibility than a timed fill or float switch. However, unlike a timed fill or a float switch, a water meter approach requires an electronic dishwasher controller that can make use of the pulses generated by the water meter.

Improved food filter

Improved food filters help prevent the re-deposition of food particles, possibly leading to one less fill for rinsing. Dishwashers utilizing fine filters have less food re-deposited on dishes, because the food is filtered out before being re-circulated by the pump through the spray arms. Another benefit is that the water supply lines, nozzles, etc. can have small cross-sections without the risk of clogging due to entrained food particles. Thus, a fine food filter can enable a manufacturer to reduce the volume of the water needed to fill all parts of the water system.

Typical filter designs have a self-cleaning feature that backwashes the filter automatically and therefore minimizes manual filter cleaning. Although less water is required overall for dishware rinsing, the washing of the filter requires water use. The task can be changed to an intermittent event via the inclusion of a pressure transducer, which can sense how clogged the filter is and thus signal a rinse requirement to an electronic controller. The filter is cleaned whenever the need arises, allowing the designer to implement lower-volume sump designs. Another implementation approach could monitor the pump motor directly to detect excessive slip, resistance, or other parameter to infer a clogged filter condition.

Improved motor efficiency

An electric motor runs the main water pump and, if separate, the drain pump as well. Dishwashers have typically used split-phase or shaded-pole motors because of their low torque requirement and constant starting current condition. A capacitor-type motor, such as a permanent split capacitor (PSC) motor, is more efficient than a split-phase or shaded-pole motor. It uses a capacitor in both the starting and running modes. The capacitor-type motor increases the power factor, and, therefore, reduces heating losses in the stator. An electric motor efficiency of 65 percent should be possible using a capacitor-type motor.

A 30-percent improvement in motor efficiency produces approximately a 2.5-percent overall reduction in dishwasher energy consumption. Dishwashers with permanent magnet motors could reduce the electrical consumption of the pump motor by a further 10–20 percent from the levels attainable with PSC motors.

Improved spray-arm geometry

Spray arms, which are typically located at the center and the bottom of a dishwasher cavity, are designed to rotate and spray pressurized water on the dishwasher contents. If the spray arms are designed to more effectively remove food particles, the dishwasher will use less hot water and energy.

Increased insulation

Some dishwashers feature some insulation to reduce noise levels. Generally, these dishwashers use bitumen attached to the wash tub to dampen noised caused by vibrations in the tub during operation. However, the added thermal mass of the bitumen insulation typically results in higher energy consumption. Other dishwashers use a cotton liner to decrease heat losses from the tub. The cotton insulates the wash tub with a lower thermal mass than bitumen. The marginal benefit for this type of additional insulation is very small.

Low-standby-loss electronic controls

Electronic controls may consume power even when the dishwasher 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 will reduce the annual energy consumption of the dishwasher, but will not impact the energy consumption of the dishwasher during operation. Low-standby-loss electronic controls can be implemented in a wide variety of ways.

Microprocessor controls and fuzzy logic, including adaptive or soil-sensing controls

Microprocessor controls and fuzzy logic, including adaptive or soil-sensing controls, are able to reduce the energy and water consumption of a dishwasher by allowing the machine to adapt to variable conditions inside the unit. Sensors located inside the dishwasher provide a stream of information, including turbidity, conductivity, temperature, and spray arm rotation, to the fuzzy logic controller which, in turn, controls the operation of the dishwasher by adjusting the amount of water used and/or the water temperature, based on inferred load and/or soil level. This is somewhat analogous to manually selecting light-, normal- or heavy-duty wash selection.

For example, some dishwasher designs have sensors that measure the amount of food soil in the water and algorithms that adjust water temperature, fill levels, and cycle time accordingly. This design feature may also track the amount of time between loads so the controller can adjust for dried-on food, as well as taking into account the number of times the door has been opened to determine load size. According to Honeywell, a key developer and supplier of soil-sensing packages, such a system can reduce energy consumption by 35 percent and water consumption by 45 percent.[46] Most manufacturers offer dishwashers using soil-sensing controls.

In 2003, the DOE test procedure was updated to more accurately measure energy efficiency for machines equipped with soil-sensing controls. For these machines, water and electrical energy consumption are measured under varying soil load conditions, and the results are averaged via a weighted formula that represents typical usage patterns.

Modified sump geometry, with and without dual pumps

The amount of water used for each cycle can be reduced by a change in the geometry of the sump and its integration with the main pump and a drain pump (if any). During the wash part of the cycle, approximately half of the water at any given time in the dishwasher is in the sump to ensure an air-free water supply to the pump. Current sump designs attempt to minimize water use while maintaining an adequate water supply to the pump. This technology option would optimize the sump to minimize the total amount of water needed per fill. Another factor in sump design is how quickly water can flow back to the sump after being sprayed on the dishes.

Many baseline dishwashers use one pump to deliver pressurized water, with detergent in solution, to the spray arms, and to drain the wash solution when the wash cycle is complete. This pump is powered by a single electric motor. By using two pumps and two electric motors, with one set optimized for washing and one set optimized for draining, the overall energy consumption due to water pumping may be decreased.

Reduced inlet-water temperature

This option uses cold temperature water for some of the rinse cycles. Dishwashers with adequate heating elements could tap only to the cold water supply line, allowing the dishwasher's heating element to heat the water as required. For reduced-temperature rinse cycles, the water would be heated to a lower temperature than the temperature of water typically available from the hot water supply line (120 °F), reducing energy consumption. The dishwasher's internal water heater may also be more efficient than the household water heater. For an example of a dishwasher incorporating this design option, ASKO manufactures a dishwasher capable of attaching directly to a cold water line.[47] However, ASKO notes that a dishwasher connected to the cold water line requires more time to complete the washing cycle, because the dishwasher requires additional time to internally heat the water to operating temperatures.

Alternatively, a dishwasher could tap both the hot and cold water lines, and mix hot and cold water in order to reduce inlet water temperatures. Again, because U.S. dishwashers are conventionally connected to a hot water line only, this option would necessitate plumbing in a cold water line to the dishwasher in addition to the currently-used hot water line.

Another means to lower rinse water temperature is to lower the hot water temperature setting on the household water heater and use the dishwasher's heating element to raise the water to the needed temperature. But lowering the household water heater temperature below 120 °F may not satisfy other household hot water requirements.

Supercritical carbon dioxide washing

At an Electrolux-sponsored design competition, students from the University of New South Wales designed a dishwasher with a cleaning process based upon supercritical carbon dioxide instead of the conventional detergent and water solution.[48] The supercritical carbon dioxide within the dishwasher behaves simultaneously as a liquid and a gas, completely filling the washing tub and covering the dishes, like a gas, but dissolving grease like a liquid. The supercritical carbon dioxide is used in a closed-loop process. After the wash cycle, contamination is removed from the carbon dioxide, which is stored for the next wash cycle.

Ultrasonic washing

Ultrasonic washing uses high frequency sound generators to create cavitation bubbles within the wash water, in which the dishware is completely submerged. These bubbles implode upon contact with a surface, effecting a mechanical scrubbing action that removes soil from the dishware. This cleaning action is not dependent on water temperature, water flow rate, or detergents, making the process highly energy efficient, because a standing pool of room temperature water may be used. However, standing ultrasonic waves within the washing cavity and the force of cavitation implosion can damage fragile dishware. Also, consumers may not perceive ultrasonic dishwashers as properly sterilizing dishes at low temperatures, resulting in a perceived decrease in consumer utility, even though not all current dishwashers operate at high enough temperatures to effectively sterilize their contents.

Sharp introduced an ultrasonic and ionic dishwasher for the Japanese market in September 2002, which utilizes a different ultrasonic technique for soil removal.[49] The dishwasher tank is partially filled with water, and a superfine mist is created using an ultrasonic generating element to remove food stains from dishes. Hard water ion washing is then performed using table salt. A prepared salt-water mixture is put through an exchange system to make hard water containing an abundance of calcium ions ($Ca2+$) and magnesium ions ($Mg2+$). This water washes the dishes using a salting-in effect to remove protein-based stains, which would otherwise become hardened and difficult to remove when using conventional heated tap water. The ion exchange system then removes calcium and magnesium ions from the tap water to create soft water for rinsing. The combination of the ultrasonic waves and the salt-water mixture is designed to wash without the need for dishwasher detergent. Unlike the technology described above, Sharp's ultrasonic dishwasher does not rely on immersing the dishes in an ultrasonically excited fluid.

Variable washing pressure and flow rates

Variable washing pressure and flow rates are being employed in some dishwasher models to reduce dishwashing cycle times or to accommodate the various levels of soiling. For example, the user can choose an option to provide a 30-percent increase in washing pressure and, thus, more rapidly (and powerfully) clean dishes. The user interface usually presents this option as, for example, a "pots and pans" wash setting versus a "normal" setting. Higher energy consumption from the dishwasher pump is required to achieve the increase in washing pressure.

Conversely, reduced washing pressure requires less energy from the dishwasher pump to run the cleaning cycles, reducing the energy consumption of the dishwasher as long as the cycle time is not increased. Such a strategy may be employed for rinse cycles, during which clean water is used to remove detergent from the dishes. Because the rinse cycle does not need high washing pressure to remove food material from soiled dishes, a reduced water pressure is feasible without degrading the overall cleaning performance of the dishwasher.

Some dishwashers alternate the delivery of water to the top-rack spray arm and the bottom-rack spray arm. This diversion is accomplished by using a valve or other fluid control mechanism to route the water to one spray arm at a time. Once the active spray arm has completed its cycle, the water may be circulated through the other spray arm to complete a similar cycle. This reduces the amount of water required by the dishwasher, because the dishwasher only heats and circulates enough water for one spray arm. By reducing the amount of water required, and therefore the amount of water heating required, alternating water delivery to the top and bottom spray arms reduces the energy consumption of the dishwasher.

In order to implement this feature, the dishwasher must be capable of adequately filtering the wash water. Because a smaller quantity of water is used to remove the same quantity of dish soiling, the water will contain a higher concentration of soiling. If the dishwasher filtering system does not adequately filter the water, re-deposition of food soiling could increase as the soiled water is circulated.

In addition to reducing the energy consumption of dishwashers washing full loads, this technology option also lets manufacturers offer dishwashers with efficient "half-load" wash cycles in which water is only routed to one spray arm, which allow consumers to run the dishwasher when it is half-full without wasting the water and energy necessary to wash a full load.

3.15.3 Energy Efficiency

In preparation for the screening and engineering analyses, DOE gathered data on the energy efficiency of dishwashers currently available in the marketplace. This data is 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 dishwashers currently available and in use, it does provide a rough representation of the range of available energy efficiencies. The CEC publishes a list of "certified" residential dishwashers. Figure 3.15.1 displays the distribution of standard dishwashers in the CEC database, as of September 12, 2011, as a function of estimated annual energy use, rounded down to 10 kWh per year intervals.

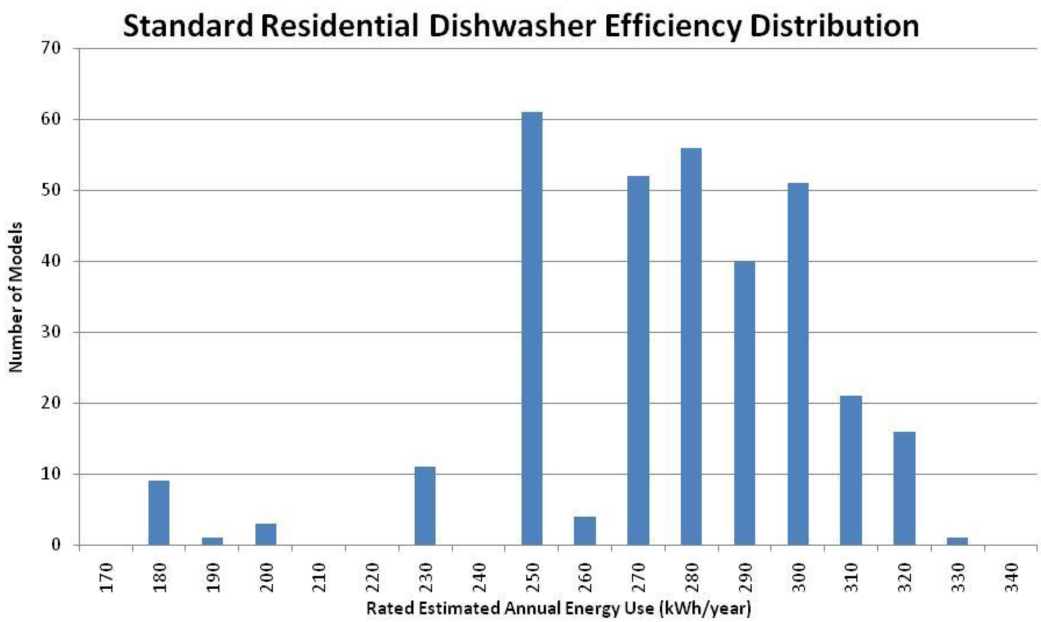


Figure 3.15.1 Standard Dishwashers in the CEC Directory[50]

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