Residential Dishwashers

Background and Current Standards

- **Energy Policy and Conservation Act of 1975 (EPCA),** P.L. 94-163
  - Authorizes DOE to establish conservation standards for covered products or equipment that would likely result in significant national energy savings
  - Specifies a list of covered residential and commercial products and contains provisions to classify additional products as covered products
- **Dishwasher standards:**
  - The National Appliance Energy Conservation Act of 1987, Pub. L. 100-12, amended EPCA and required an unheated drying option for dishwashers
  - Energy conservation standards Final Rules:

    1991 (56 FR 22250), effective May 14, 1994

    2009 (74 FR 12058), effective January 1, 2010
    - Codifies amended standards set by the Energy Independence and Security Act of 2007

    2012 (77 FR 31918), effective May 30, 2013 (current standards)
    - Submitted to DOE by groups representing manufacturers, energy and environmental advocates, and consumer groups on September 25, 2010

    2016 (81 FR 90072), did not amend standards for dishwashers, concluding that potential standards were not economically justified

Dishwashers: Market Overview

DOE defines residential dishwashers 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."

	Residential Dishwashers	
Annual Shipments (2017)	8.0 million	
Total Energy Use (quads/year)	0.31	
Percentage of Total U.S. Residential Energy Use	1.5%	
Average Product Lifetime (years)	15.2	
	Standard	**Compact**
Percentage of Annual Shipments	99%	1%
Baseline Energy Consumption (kWh/year)	307	222
Baseline Water Consumption (gallons/cycle)	5.0	3.5

Dishwashers: Regulatory History

The current dishwasher standards for water and energy consumption were established in May 2012 and became effective on May 30, 2013. The standard is established for the normal cycle of dishwashers.

Product Class	Energy Use	Water Use
Standard dishwashers	307 kWh/year	5.0 gallons/cycle
Compact dishwashers	222 kWh/year	3.5 gallons/cycle

- DOE published a Direct Final Rule on May 30, 2012 in response to a consensus recommendation for energy conservation standards for residential dishwashers.
- DOE published a Notice of Proposed Rule Making (NPRM) on December 19, 2014 (2014 NPRM), which satisfied the EPCA provision of 6-year lookback.
- In the Final Rule published on December 13, 2016, DOE concluded that amended energy conservation standards would not be economically justified at any level above the 2012 Final Rule and, therefore, determined not to amend the current standards.

Dishwashers: Market Failures

Pursuant to complying with Executive Order 12866, DOE identified market failures to justify the 2014 NPRM of dishwasher energy conservation standards. The Final Rule was determined to be not significant for the purposes of Executive Order 12866.

Section 1(b)(1) of Executive Order 12866, ‘‘Regulatory Planning and Review,’’ 58 FR 51735 (October 4, 1993), requires each agency to identify the problem that it intends to address, including, where applicable, the failures of private markets or public institutions that warrant new agency action, as well as to assess the significance of that problem.

DOE identified the following problems:

- There may be a lack of consumer information and/or information processing capability about energy efficiency opportunities in the dishwasher market.
- There is asymmetric information among parties to a transaction and high costs of gathering information.
- There are external benefits resulting from energy efficiency that are not captured by the users of the equipment, e.g. benefits related to environmental protection, such as reduced emissions of greenhouse gasses.

Current Dishwasher Product Classes

- DOE established two product classes for dishwashers for standards effective in 1994.* (56 FR 22250)
- Dishwashers are currently classified according to capacity: the number of place settings of dishware that can be cleaned.

Standard: 8 or more place settings + 6 serving pieces

- 24” and 18” wide
- Built-in and portable
- Dual-drawer



Compact: Less than 8 place settings + 6 serving pieces

- Countertop
- Single-drawer


* For standards effective in 1994, DOE established compact and standard product classes based on exterior width. In a 2001 test procedure Final Rule, DOE changed the definition to be based on place settings.

Dishwasher Technology Options

DOE identified the following technology options as having the potential to reduce energy or water consumption and considered these technology options further in the Screening Analysis:

Dishwasher Technology Options (2016 Final Rule)	
Condensation Drying	Low-Standby-Loss Electronic Controls
Control Strategies	Microprocessor Controls, Including Soil Sensing
Fan/Jet Drying	Modified Sump Geometry
Flow-Through Heating	Separate Circulation and Drain Pumps
Higher Efficiency Motor	Variable Washing Pressures and Flowrates
Improved Fill Control	Desiccant Drying*
Improved Food Filter	Reduced Inlet Water Temperature*
Improved Spray-Arm Geometry	Supercritical Carbon Dioxide Washing*
Increased Insulation	Ultrasonic Washing*

***Screened out options**

DOE identified technology options from:

- Documents from previous dishwasher rulemakings
- Literature review and manufacturer specification sheets
- Product teardowns

Dishwasher Screening Analysis

Technologies eliminated from consideration due to meeting one or more of the screening criteria:

Technology Option	Applicable Screening Criteria
Desiccant Drying	Would not be practicable to manufacture on the scale necessary for the residential dishwasher market. Desiccant drying is a patented technology, and although multiple manufacturers hold patents for dishwasher designs with desiccant drying features, DOE is concerned that this technology option is not available for all manufacturers.
Reduced Inlet Water Temperature	Practicability to manufacture, install, and service. Most residential dishwasher installation locations are supplied by a hot water line.
Supercritical Carbon Dioxide Washing	Practicability to manufacture, install, and service; possible impacts on product utility to consumers. Technology is still at the research stage and DOE cannot assess potential adverse impacts.
Ultrasonic Washing	Possible impacts on product utility to consumers. Ultrasonic washing could damage fragile dishwasher; manufacturers are not producing this technology and DOE cannot assess potential adverse impacts.

Dishwasher Utility and Performance Issues

In addition to screening out individual technology options based on product utility concerns, DOE also considers establishing separate product classes to ensure that consumer utility is preserved.

2016 Final Rule: Product class consideration for high-capacity dishwashers

- Stakeholders commented that **higher-capacity units** than currently available (>16 place settings) could come to market.
- Stakeholders questioned whether the analysis would be representative of such units and whether such units could achieve the same higher standard levels as current units.
- DOE concluded that, at the time, no alternate product class was required.
- However, should higher-capacity units enter the market, DOE could consider evaluating whether separate standards are warranted.

2019 Petition for Rulemaking: Product class consideration for 1-hour cycle time

- DOE is undertaking a rulemaking in response to a petition put forward by the Competitive Enterprise Institute (CEI) to define a new product class for dishwashers with a **cycle time of <1 hour** (from washing through drying).
- DOE has initially decided to grant the petition for rulemaking and is in the process of reviewing comments from interested parties.

Dishwasher Engineering: Representative Equipment

- **Choose Representative Equipment**
- Define Baseline Models
- Analyze More Efficient Designs
- Calculate MPCs
- Generate Cost Curves

Product Classes: Standard vs. Compact

Standard dishwashers
(≥8 place settings)

Compact dishwashers
(<8 place settings)

Dishwasher Engineering: Baseline Models

- Choose Representative Equipment
- **Define Baseline Models**
- Analyze More Efficient Designs
- Calculate MPCs
- Generate Cost Curves

DOE selected baseline efficiency levels (ELs) consistent with the May 2013 standards.

Product Class	Efficiency Level	
	kWh/year*	gal/cycle*
Standard	307	5.0
Compact	222	3.5

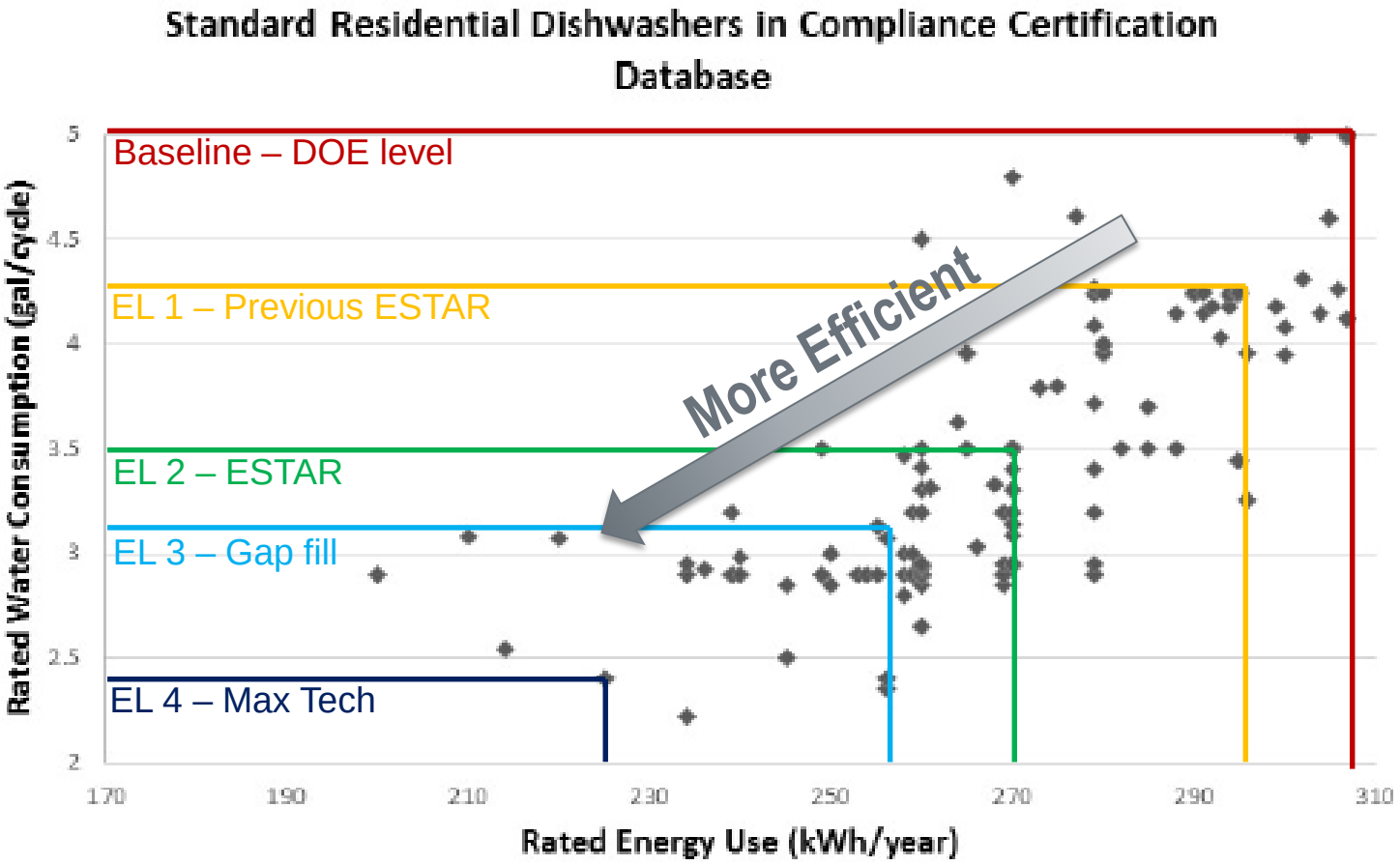
*Energy and water metrics are calculated as a weighted average of three test runs: light, medium, and heavy food soil loads for soil-sensing dishwashers, which comprise the significant majority of units on the market.

Pictured: Heavy soil load

Dishwasher Engineering: ELs

- Choose Representative Equipment
- Define Baseline Models
- **Analyze More Efficient Designs**
- Calculate MPCs
- Generate Cost Curves

DOE identified ELs that it analyzed to develop cost-efficiency curves by researching the performance of models of commercially available dishwashers.



Dishwasher Engineering: Design Path

- Choose Representative Equipment
- Define Baseline Models
- **Analyze More Efficient Designs**
- **Calculate MPCs**
- Generate Cost Curves

Product teardowns and manufacturer interviews were used to determine the likely design options at each analyzed EL.

Teardowns

- Identify presence of design options
- Determine implementation strategy
- Conduct detailed cost modeling of design options and related components

Manufacturer Interviews

- Confirm effectiveness and necessity of design options at certain ELs
- Provide feedback on estimated design option costs
- Determine non-efficiency aesthetic components

Dishwasher Engineering Analysis: Design Path

Illustrative example of how observed designs and manufacturer feedback inform the final analyzed design at each EL:

Technology Component	Baseline Construction	EL 1 Characterization			Final Analyzed Design for EL 1
		Unit 1 Teardown	Unit 2 Teardown	Manufacturer Feedback	
Control	Electro-mechanical	Electronic	Electronic	Electronic	Electronic
Soil Sensor	No	Yes	Yes	No	No
Tub Type	Plastic	Stainless	Plastic	Plastic	Plastic
Heater	In-tub	In-tub	In-tub	In-tub	In-tub
Spray Arms	1	2	2	2	2
Drain Pump	No	Yes	Yes	Yes	Yes

Shading indicates technology step-up from baseline level.

- Analysis only considered increased production costs associated with design options (e.g., stainless steel doors observed at higher ELs did not factor into increased MPC at higher ELs)

Dishwasher Engineering: Price-Efficiency Relationship

Choose Representative Equipment

Define Baseline Models

Analyze More Efficient Designs

Calculate MPCs

Generate Cost Curves

DOE generated cost-efficiency results for each product class.

- DOE determined the incremental cost for manufacturers to achieve increasing standard levels.

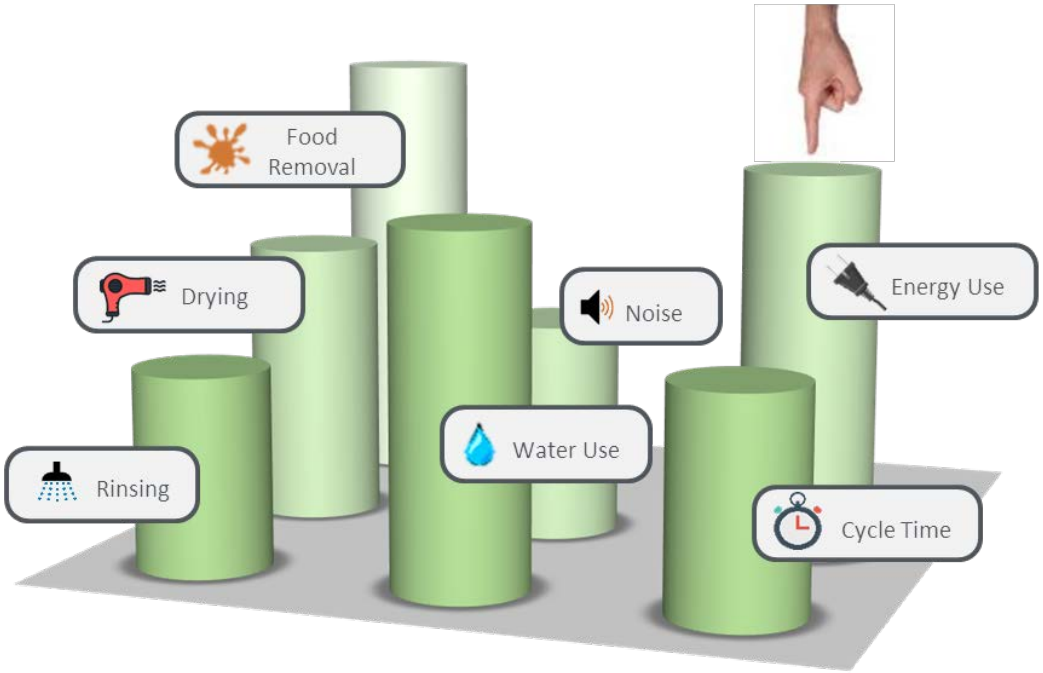
Product Class	Level	EL		Incr. MPC
		kWh/year	gal/cycle	
Standard	Baseline	307	5.0	$-
	EL 1	295	4.25	$14.76
	EL 2	270	3.5	$42.20
	EL 3	255	3.1	$57.61
	EL 4	225	2.4	$92.20
Compact	Baseline	222	3.5	$-
	EL 1	203	3.1	$8.50
	EL 2	130	1.7	$28.11

- Baseline represents least efficient unit (current standard)

Dishwasher Engineering: Stakeholder Issues

Product Performance and Consumer Utility

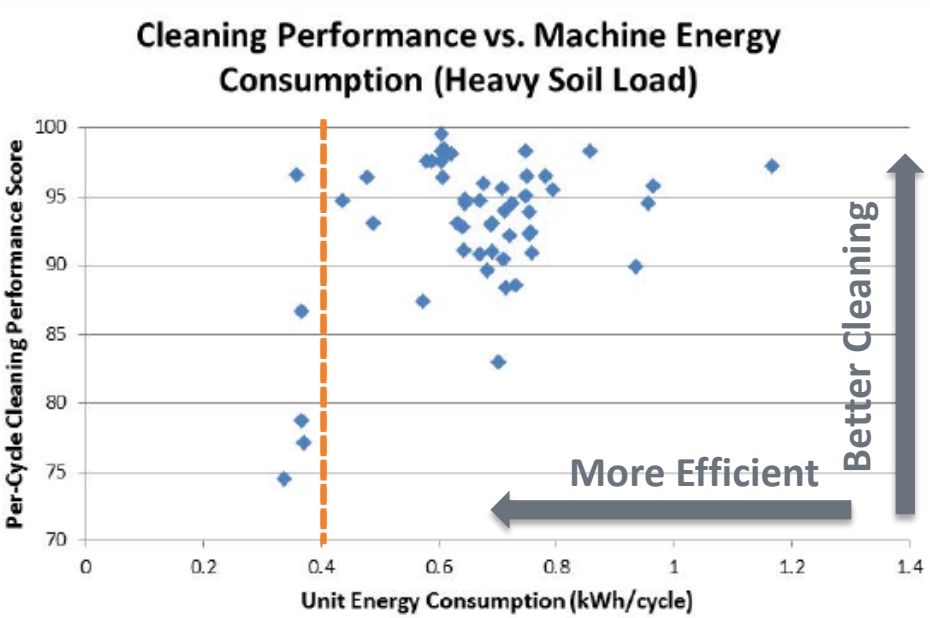
- Technology options are screened out from further consideration in DOE's analysis if they are determined to have a significant adverse impact on product utility (see Screening Analysis discussion).
- For dishwashers, impacts on product utility are not necessarily tied to specific design options due to the interconnected nature of the different aspects of performance.

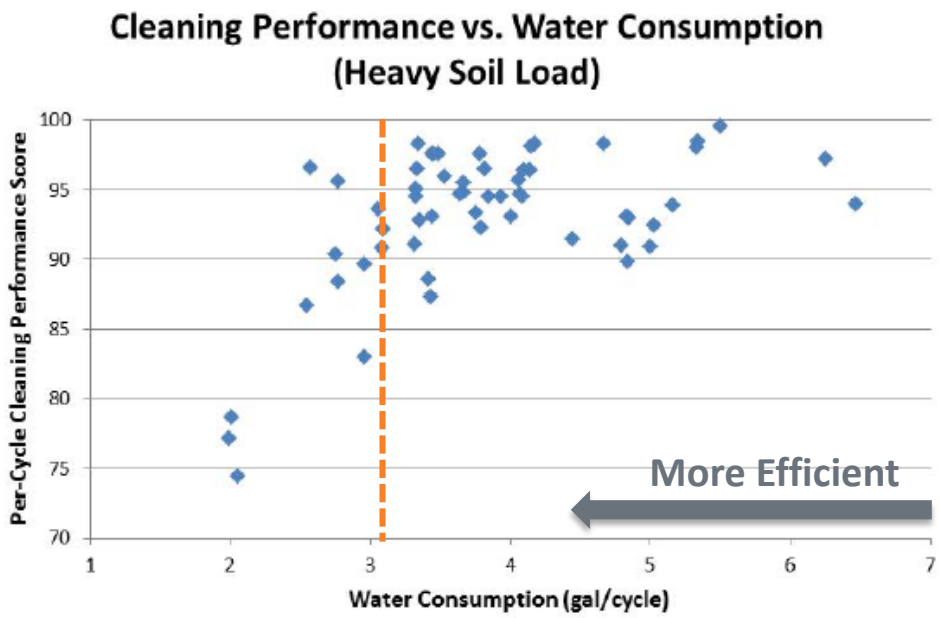


Dishwasher Engineering: Stakeholder Issues

Product Performance and Consumer Utility

- DOE considered potential impacts on product utility when establishing ELs in the Engineering Analysis.
- In the NPRM Analysis, DOE established the gap fill level (EL 3) at the minimum energy and water threshold where cleaning performance could be maintained based on available test data.

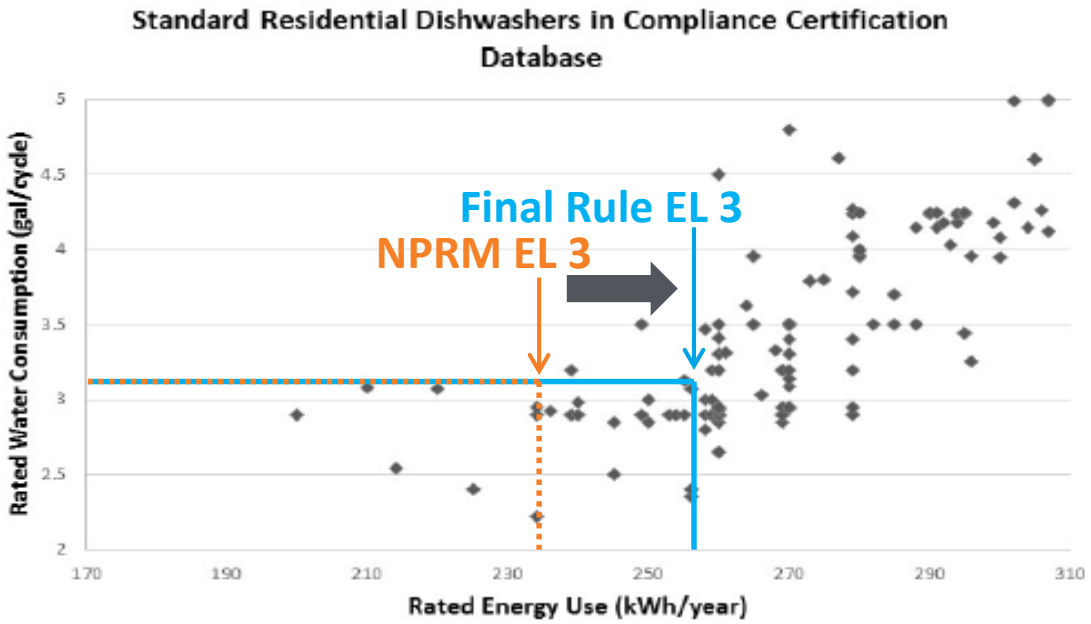




Dishwasher Engineering: Stakeholder Issues

Product Performance and Consumer Utility

- In response to the NPRM, DOE received comments indicating that performance would be adversely affected at the analyzed EL 3.
- During manufacturer interviews after the NPRM, DOE received feedback that dishwashers could maintain performance at the NPRM EL 3 water use paired with a higher energy use (in the range of 250 to 260 kWh/yr).
  - DOE increased the energy use for EL 3 to 255 kWh/yr in the Final Rule analysis.
- Association of Home Appliance Manufacturers (AHAM) and its members then presented information indicating that the revised EL 3 could still impact performance.
- Given that AHAM's data was based on heavier soiling conditions than typical consumer use, the data was not directly comparable.
- DOE noted concerns about the potential for negative utility impacts in the Final Rule policy choice explanation.



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Markups Analysis

Purpose

- Determine consumer prices based on manufacturer's selling price (MSP) for baseline and higher efficiency equipment.
- Characterize product distribution channels.

Method

- Analyze company direct costs, expenses, and profits. Manufacturer markups are estimated in the Engineering Analysis and are based on SEC 10-K reports.
- Retailer markups are based on U.S. Census *Annual Retail Trade Survey*
- Sales taxes are based on *The Sales Tax Clearinghouse*

Markups Analysis

Baseline Markups

- Relate the MSP of baseline product to the consumer purchase price.
- Indicate a consumer price that covers the retailer's expenses plus profit.

Incremental Markups

- Relate the increase in MSP of more efficient products to the increase in consumer purchase price.
- Efficiency improvements affect some distribution costs but not others. DOE sets markups and retail prices to cover the distribution costs expected to change with efficiency but not the distribution costs that are not expected to change with efficiency.
- Separate variable and fixed costs to establish incremental markups.

Bagwell, K., & H. Riordan, 1991. High and Declining Prices Signal Product Quality. The American Economic Review, 81 (1).

Betts, E., & J. M. Peter, 1995. The strategy of the retail 'sale': typology, review and synthesis. The International Review of Retail, Distribution and Consumer Research, 5 (3).

Elmaghraby, W. & P. Keskinocak, 2003. Dynamic Pricing in the Presence of Inventory Considerations: Research Overview, Current Practices, and Future Directions. Management Science. 49.

Dale, L., et al., 2004, An Analysis of Price Determination and Markups in the Air-Conditioning and Heating Equipment Industry. LBNL-52791

Markups Analysis

- Analysis assumes that standards do not facilitate a sustainable increase in retailer profitability. Analysis estimates markups/gross margins to allow cost recovery for retail companies in the distribution channel (including changes in the cost of capital) without changes in company profits.
- Any increase in retailer profitability resulting from an increase in MSP is not likely to be viable over time in a business that is reasonably competitive or in markets with a limited degree of concentration.
- Empirical data on markup practices, particularly in response to price perturbations in a complex market, are difficult to obtain and largely proprietary.
- Price data from other industries that experienced rapidly changing input prices indicate that the percent margins do not remain fixed over time in any of these industries.

Markups Analysis (NPRM)

Table 6.3.3 Data for Calculating Incremental Markup: Electronics and Appliance Stores

Business Item	Amount ($1,000,000)
Sales	110,673
Cost of goods sold (CGS)	*81,234*
Gross margin (GM)	*29,439*
Labor & Occupancy Expenses (invariant)	
Annual payroll	11,714
Employer costs for fringe benefit	1,829
Contract labor costs, including temporary help	154
Purchased utilities, total	623
Cost of purchased repair and maintenance services	369
Cost of purchased professional and technical services	1,164
Purchased communication services	396
Lease and rental payments	3,576
Taxes and license fees (mostly income taxes)	619
Subtotal:	20,444
Other Operating Expenses & Profit (variant)	
Expensed equipment	114
Cost of purchased packaging and containers	68
Other materials and supplies not for resale	502
Cost of purchased transportation, shipping, and warehousing services	606
Cost of purchased advertising and promotional services	2,625
Cost of purchased software	159
Cost of data processing and other purchased computer services, except communications + commissions paid	368
Depreciation and amortization charges	1,525
Other operating expenses	2,070
Net profit before tax (operating profit)	*958*
Subtotal:	8,995
Incremental markup = (CGS + Total Other Operating Expenses and Profit)/CGS	1.11

Source: U.S. Census. *2007 Annual Retail Trade Survey* (for sales), and *2011 Annual Retail Trade Survey* (for GM and CGS).

Markups Analysis: Overall Markups

	Standard and Compact Product Classes (NPRM)		Standard and Compact Product Classes (Final Rule)	
Markup	Baseline	Incremental	Baseline	Incremental
Manufacturer	1.24		1.24	
Retailer	1.36	1.11	1.39	1.13
Sales Tax	1.071		1.071	
Overall	1.81	1.47	1.85	1.50

- Applied baseline markups to the MSP of the baseline level and the incremental markups to the incremental difference in MSP at each level above the baseline.

Energy and Water Use Analysis

Purpose

- Determine annual energy and water use at the considered ELs
- Use annual energy and water use to determine cost inputs to LCC and PBP Analysis

Method

- Use research studies and Engineering Analysis data to develop per-cycle energy use by EL
- Use RECS 2009 to develop frequency ranges for annual energy and water use of sampled U.S. households.

Total Energy Use

- Machine energy + water heating energy + drying energy

Energy and Water Use Analysis (NPRM)

- Analysis depends on cycles per year
- Average value of 215 cycles/year from ADL study on dishwasher usage with survey data from 1997 RECS, dishwasher manufacturers, detergent manufacturers, consumer groups, academia, and government agencies
- Distribution of usage from 2009 RECS data, scaled so that average equals 215 cycles/year

Figure 7.4.1 **Distribution of Annual Dishwasher Use (Cycles per Year) Based on 2009 RECS Usage Data**

Energy and Water Use Analysis (Final Rule)

- Revised analysis of 2009 RECS data
- Replaced the RECS value in average calculation of multiple surveys from ADL report
- New average is 207 cycles/year

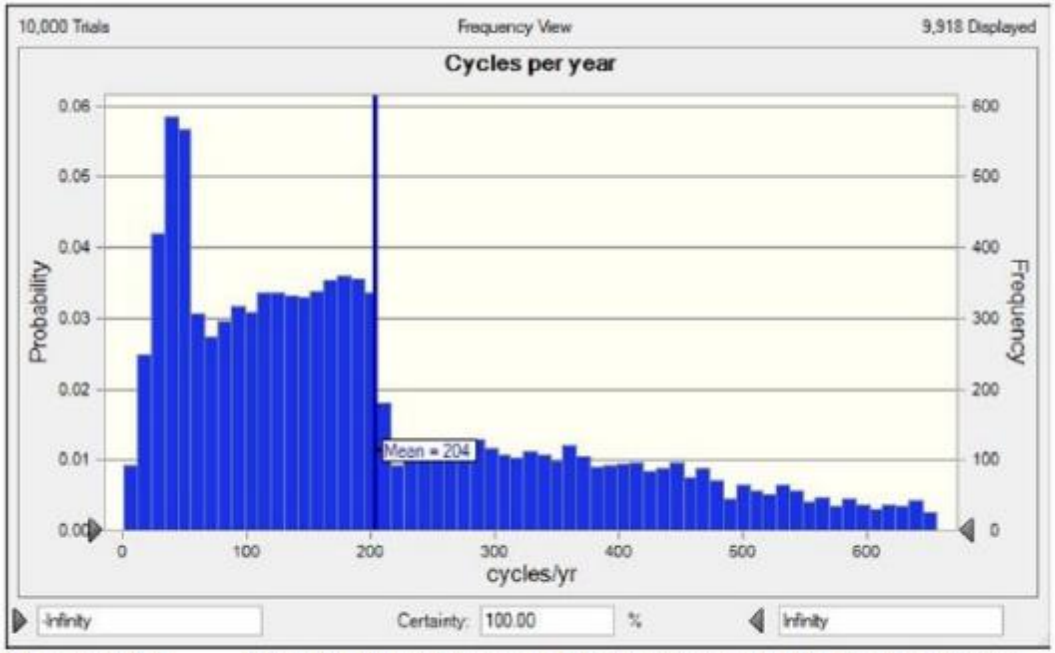


Figure 7.4.1 Distribution of Annual Dishwasher Use (Cycles per Year) Based on 2009 RECS Usage Data

Product Price Trend

- DOE applied a price trend (also referred to as learning or experience curves) to dishwasher prices to determine product prices in future years.
- Analysis is based on producer price index (PPI) data for "other miscellaneous household appliances" to estimate price as a function of cumulative shipments.

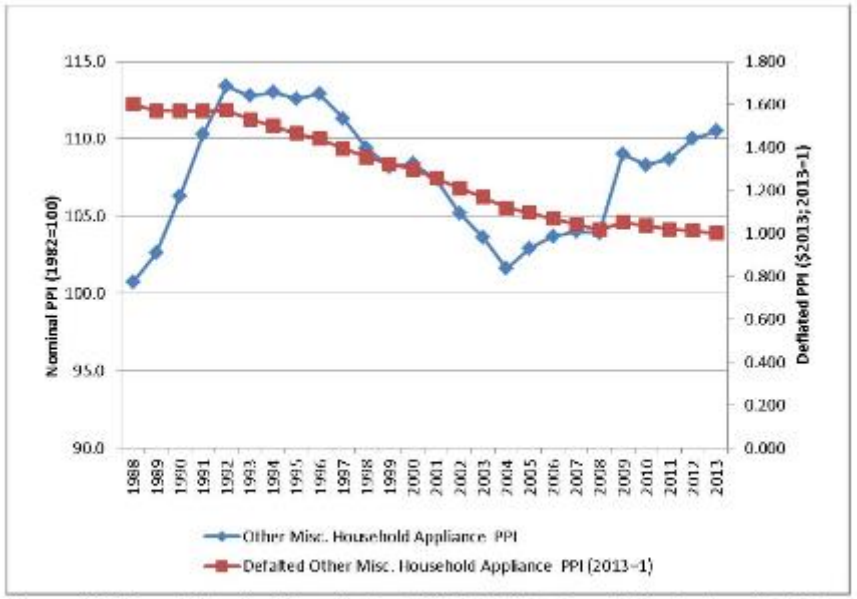


Figure 8-C.1 Historical Nominal and Defalted Producer Price Indexes for Other Miscellaneous Household Appliances

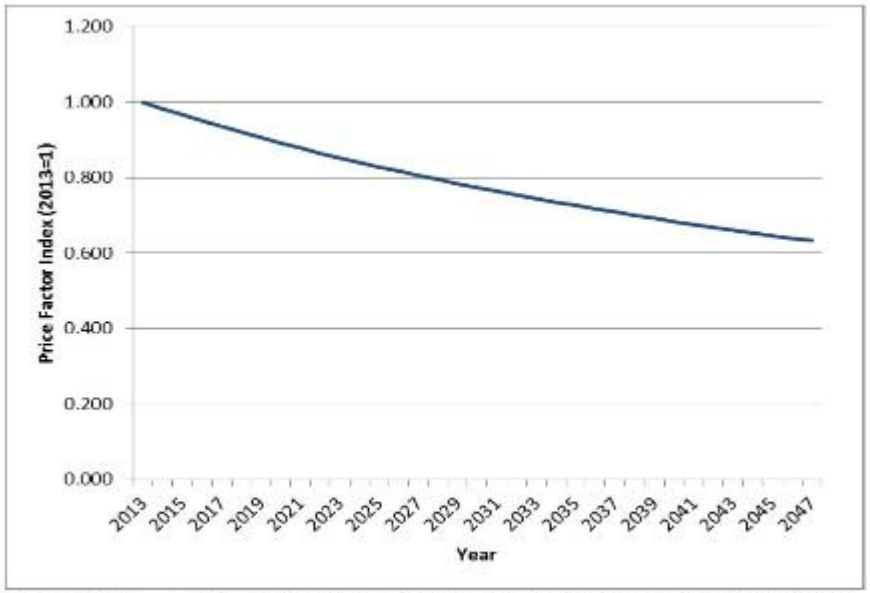


Figure 8-C.4 Price Factor Index for the Default Case, Other Miscellaneous Household Appliances

Desroches, L., et al., 2013. Incorporating Experience Curves in Appliance Standards Analysis. Energy Policy 52, 402-416.

Life Cycle Cost (LCC) and Payback Period (PBP) Analysis

Product lifetime: Base product lifetime on a Weibull probability distribution of historical shipments data, saturations from Residential Energy Consumption Survey (RECS), and American Housing Survey. The average lifetime for both product classes: 15.4 years (NPRM), 15.2 years (Final Rule).

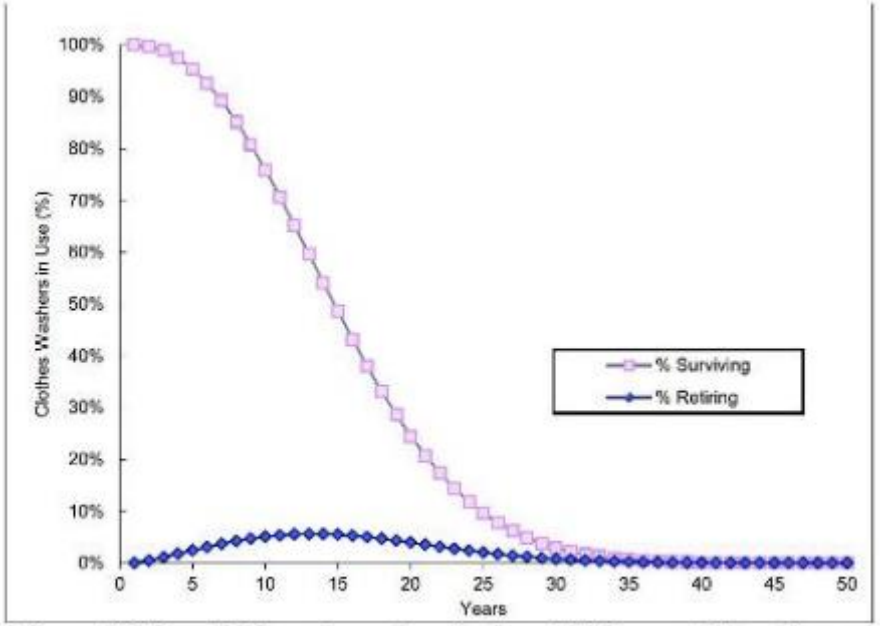


Figure 9.3.3 Dishwashers: Survival and Retirement Functions

Lutz, James D. et al., 2011, Using national survey data to estimate lifetimes of residential appliances, HVAC&R Research, 17:5, 726-736,
DOI: 10.1080/10789669.2011.558166

LCC and PBP Analysis: Energy Efficiency in the Base Case

- Analyze standard levels relative to a baseline EL.
- Define base case (no new standards) efficiency distributions from the percentage of products being purchased at various ELs.
- Use historical shipments weighted base case efficiency trend (2002-2009) to estimate base case efficiency in the year of compliance (2019).

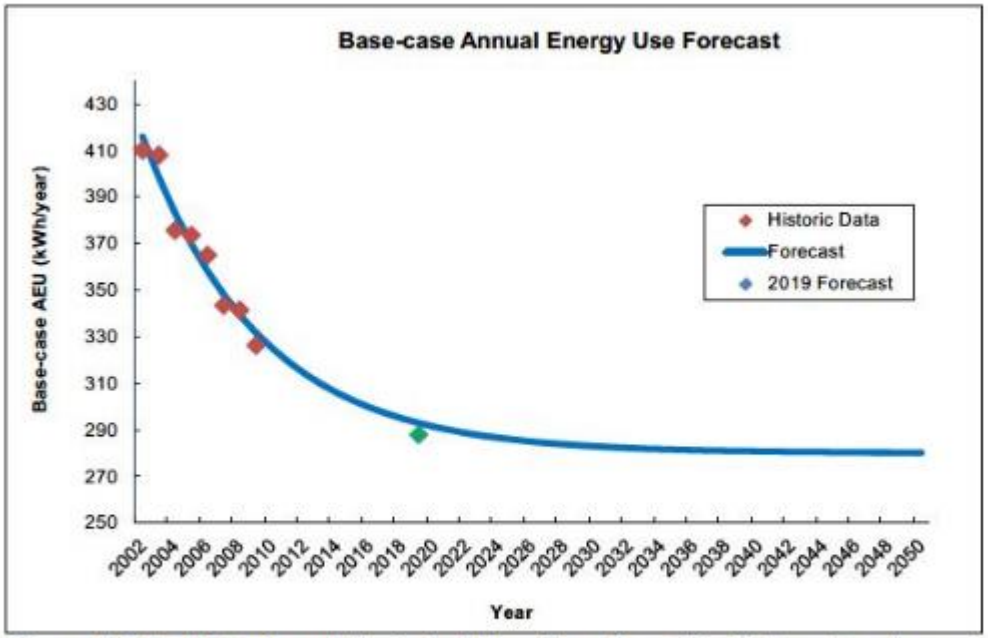


Figure 8.2.4 Historic and Projected Base Case Trend in Dishwasher Average Energy Use

LCC and PBP Analysis: Energy Efficiency in the Base Case

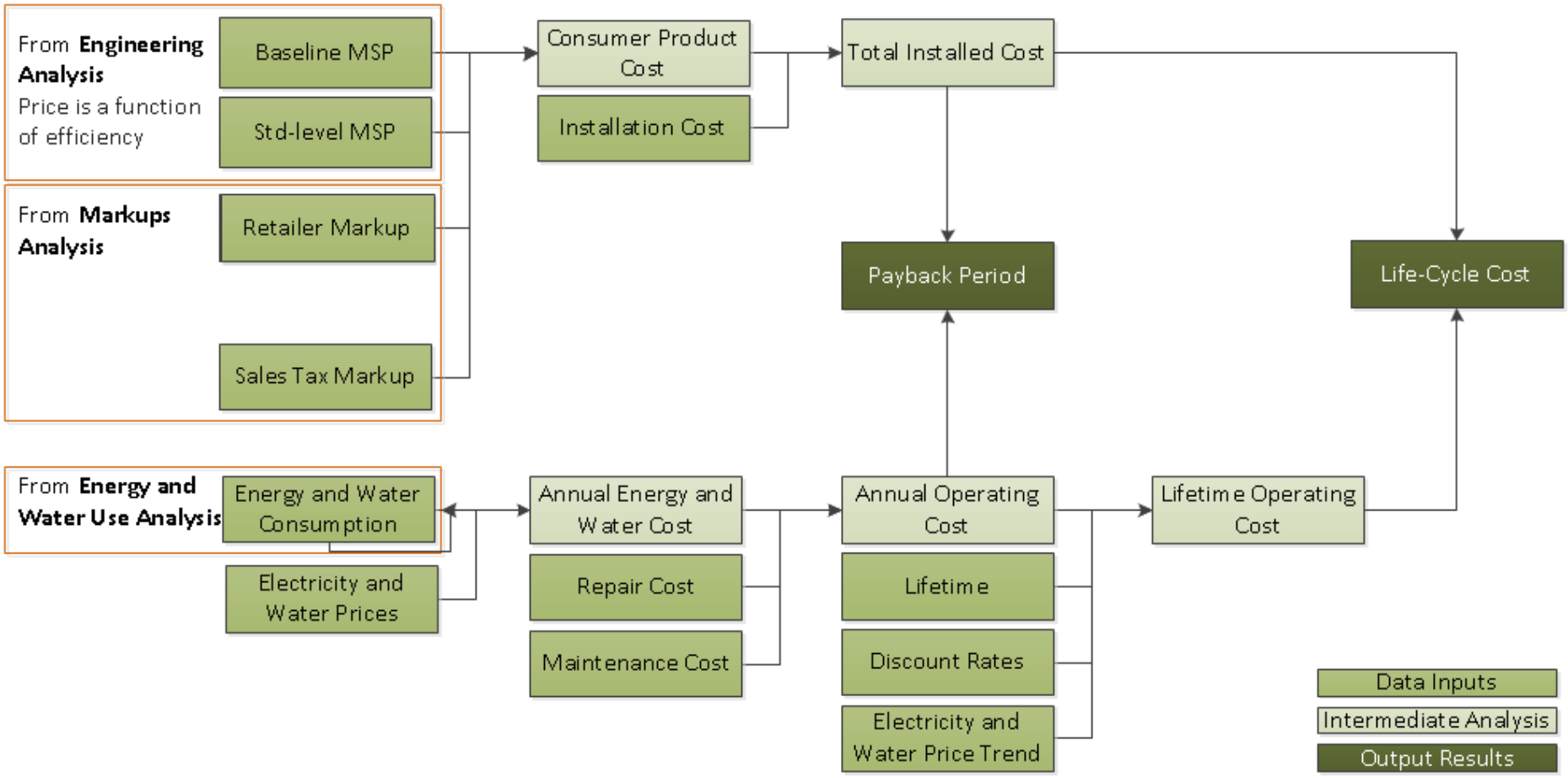
Standard Dishwashers: Base Case Efficiency Distribution in 2019

EL	Market Share (NPRM)	Market Share (Final Rule)
Baseline	12.1%	6.5%
1	43.9%	31.2%
2	40.3%	51.6%
3	3.2%	10.2%
4	0.4%	0.4%

Compact Dishwashers: Base Case Efficiency Distribution in 2019

EL	Market Share (NPRM)	Market Share (Final Rule)
Baseline	48.1%	37.0%
1	14.8%	51.9%
2	37.0%	11.1%

LCC and PBP Overview



LCC and PBP Analysis: Results (NPRM)

Standard Dishwashers: LCC and PBP Results

EL	LCC 2013$			LCC Savings		Simple Payback years
	Total Installed Cost ($)	Average Lifetime Operating Cost ($)	Average LCC ($)	Average Savings ($)	% of Consumers with Net Cost (%)	
Baseline	483	518	1,000	--	--	--
1	495	492	987	2	6	6.1
2	531	462	993	(2)	39	10.8
3	582	387	970	21	53	9.0
4	582	296	879	112	33	5.3

Compact Dishwashers: LCC and PBP Results

EL	LCC 2013$			LCC Savings		Simple Payback years
	Total Installed Cost ($)	Average Lifetime Operating Cost ($)	Average LCC ($)	Average Savings ($)	% of Consumers with Net Cost (%)	
Baseline	456	302	758	--	--	--
1	467	274	741	8	9	4.5
2	485	188	673	51	6	2.9

LCC and PBP Analysis: Results (Final Rule)

Standard Dishwashers: LCC and PBP Results

EL	LCC 2015$			LCC Savings		Simple Payback years
	Total Installed Cost ($)	Average Lifetime Operating Cost ($)	Average LCC ($)	Average Savings ($)	% of Consumers with Net Cost (%)	
Baseline	411	481	893	--	--	--
1	432	465	896	(1.94)	4	16.1
2	470	428	898	(1.07)	25	13.5
3	491	405	897	0.28	58	12.9
4	539	361	900	(3.14)	67	12.9

Compact Dishwashers: LCC and PBP Results

EL	LCC 2015$			LCC Savings		Simple Payback years
	Total Installed Cost ($)	Average Lifetime Operating Cost ($)	Average LCC ($)	Average Savings ($)	% of Consumers with Net Cost (%)	
Baseline	445	352	798	--	--	--
1	457	323	781	17	8	4.8
2	485	213	698	90	12	3.3

Consumer Choice Modeling

- Discussion in literature suggests demand for appliances is somewhat inelastic.
- Price elasticity estimate is based on appliance market data from 1980 to 2002.
- Short-run relative price elasticity of demand in standards case:
  -0.34 (NPRM), -0.45 (Final Rule)
  - Dale, L. & K. S. Fujita (2008). An analysis of the price elasticity of demand for household appliances. LBNL - 326E.
  - Update: Fujita, K. (2015), *Estimating Price Elasticity using Market-Level Appliance Data*. LBNL-188289.
- Long-run relative price elasticity of demand in standards case declines over 20 years.
- Standards case efficiency distribution assumes a "roll-up" scenario.
  - Consumers below trial standard level would roll up to new standard level, while other consumers would be unaffected.

Shipments Analysis

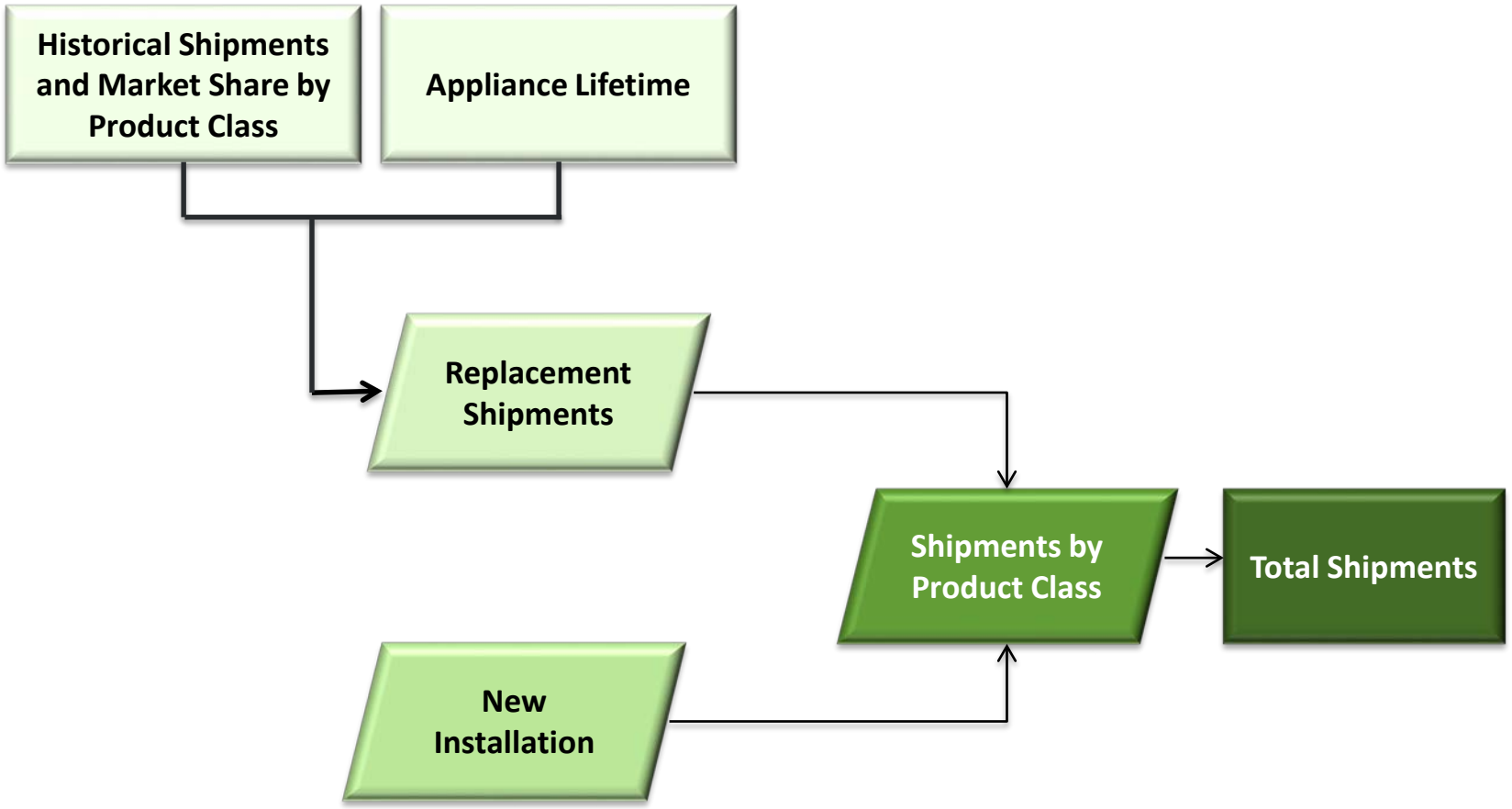
Purpose

- Quantify changes over time of product shipments due to possible new energy efficiency standards.
- Estimate the disaggregation of shipments into product classes and change in shipments by product class over time.

Method

- Use historical shipments, and RECS data for stock estimations.
- Account for replacements and new installations.

Shipments Analysis: Modeling Approach



Shipments Analysis: Model Inputs

Inputs	Data Source/Description
Historical Shipments	Total dishwasher shipments data: - Appliance Magazine (1972-1988) - Association of Home Appliance Manufacturers (AHAM) Fact Book (1989-1994) - AHAM (2000-2010) - Appliance Design (2011-2012)
Shipments by Product Class	Market share by product class: NPD Group data (2001-2011). - Standard Dishwashers: 99.2% - Compact Dishwashers: 0.8%
Replacement	Dishwasher lifetime retirement function developed from LCC Analysis - Average lifetime = 15.4 years
New Installation	New installation estimated using Annual Energy Outlook (AEO) 2014 new housing starts.
Product Price and Operating Costs	LCC provides product prices for 2019. Product price trend is applied to product price for the period 2019 – 2048. Future operating costs estimated using AEO 2014 energy price trends and Consumer Price Index (CPI) national water price index trend.

Shipments Analysis: Base Case vs. Standards Case

Base Case (No New Standards) Shipments Projection

- Capture base case shipments projection when new standards are not adopted.
- Project shipments to account for replacements and new installation.
- Develop base case projections for product classes.

Standards Case Shipments Projection

- Project shipments for the base case using historical shipments.
- Develop standards case projections accounting for purchase price increases and operating cost savings.
- Projections account for some households that forego new appliance purchase (i.e. a price elasticity is applied)

Consumer Subgroup Analysis

Purpose

- Evaluate the economic impacts of standards on consumer subgroups who may be disproportionately impacted compared with the general user population.

Method

- Identify senior-only and low-income households.

Results

- LCC and PBP results were not appreciably different than for the general population.

Manufacturer Impact Analysis: Key Issues

DOE relied on information gathered from manufacturer interviews conducted in support of the May 2012 Direct Final Rule, as well as additional interviews conducted in Spring 2015.

The following key issues, related to the focus areas, were identified:

- **Impact on dishwasher performance**
  - Industry stakeholders raised concerns about wash performance, drying performance, cycle time, and noise levels at proposed levels.

- **Regulatory cycle and burden**
  - Stakeholders were critical of DOE amending the test procedure parallel to proposing amended standards, as the concurrent process increases the burden and uncertainty on manufacturers .

MIA: Results

Range of MIA for residential dishwashers:

	Units	Base Case	Trial Standard Level	
			1	2
Industry Net Present Value (INPV)	2015$ millions	527.7	327.0 – 464.7	324.4 – 459.3
Change in INPV	2015$ millions	–	(200.7) – (63.0)	(203.3) – (68.3)
	%	–	(38.0) – (11.9)	(38.5) – (13.0)
Total Conversion Costs	2015$ millions	–	234.8 – 162.8	238.0 – 169.4
Free Cash Flow	2015$ millions	39.4	(51.9) – (19.5)	(53.2) – (22.4)
	% change	–	(231.9) – (149.6)	(235.1) – (156.8)

Upper Bound

- The upper bound to industry profitability is the scenario where capital conversion costs are lower, those based on the 2016 engineering model, and the preservation of gross margin markup scenario.

Lower Bound

- The lower bound to industry profitability is the scenario where capital conversion costs are higher, those based on the 2012 Direct Final Rule, and the preservation of operating profit markup scenario.

MIA: Cumulative Regulatory Burden

Manufacturers of residential dishwashers have been facing other DOE standards.

Regulation	Number of Manufacturers*	Manufacturers from Today's Rule**	Approximate Standards Year	Industry Conversion Costs (Millions $)	Industry Conversion Cost / Revenue†
Residential Microwave Ovens 78 FR 36316 (June 17, 2013)	14	9	2016	$43.1 million (2010$)	**0.6%**
Commercial Refrigeration Equipment 79 FR 17725 (March 28, 2014)	54	1	2017	$184.0 million (2012$)	**2.0%**
Packaged Terminal AC 80 FR 43162 (July 21, 2015)	12	2	2017	N/A	**N/A**
Automatic Commercial Ice Makers 80 FR 4645 (Jan. 28, 2015)	16	4	2018	$25.1 million (2013$)	**2.5%**
Residential Clothes Washers 77 FR 32308 (May 31, 2012)	13	10	2018	$418.5 million (2010$)	**2.3%**
Commercial Clothes Washers 79 FR 74492 (Dec. 15, 2014)	6	3	2018	$10.2 million (2013$)	**2.2%**
Dehumidifiers 81 FR 38338 (June 13, 2016)	30	4	2019	$52.5 million (2014$)	**4.5%**
Kitchen Ranges and Ovens 81 FR 60784 (Sep. 2, 2016)	21	11	2019	$119.2 million (2015$)	**0.8%**
Portable ACs 81 FR 38398 (June 13, 2016)	10	3	2021	$302.8 million (2014$)	**8.6%**

* The total number of manufacturers identified in the rule contributing to CRB.
** The number of manufacturers also producing dishwashers contributing to CRB.
† Conversion costs as a percentage of cumulative revenue for the industry during the conversion period.

MIA: Small Business Impacts

DOE did not identify any small businesses that manufacture dishwashers.

Small Business Search:

- DOE used the Small Business Administration (SBA) threshold (effective January 22, 2014) and the North American Industry Classification System (NAICS) code to determine if there were any small businesses manufacturing dishwashers.

SBA's employee limit of a small business for the NAICS code that includes residential dishwashers

Industry Description	Revenue Limit	Employee Limit	NAICS Code
Other Major Household Appliance Manufacturing	N/A	1,000	335228

Indirect Employment Impacts

- Direct employment impacts are analyzed in the MIA
- Indirect employment impacts are estimated using ImSET, an input/output econometric model of the U.S. economy
- Indirect employment impacts are estimated to be short-term effects primarily in the following sectors
  - Production/retail sector
  - Energy generation sector
  - General consumer good sector
- NPRM assumed 93% of dishwashers are produced domestically; 7% are imported
  - Net employment impact depends on assumptions of return to U.S. economy on imports
- Indirect employment impacts are likely to be transitory

Emissions Analysis

Purpose

- Estimate the emissions reductions resulting from amended energy conservation standards.
- Includes estimating considers full-fuel-cycle emissions: both power plant emissions and upstream emissions.
- Includes fugitive methane emissions.

Method

- Provide from National Impact Analysis an annual time-series of energy savings over the analysis period.
- Use Energy Information Administration's National Energy Modeling System (NEMS) to represent the impacts of amended standards.

Coughlin, Katie, et al, 2013. Modeling the Capacity and Emissions Impacts of Reduced Electricity Demand. LBNL-6092E.

Coughlin, Katie, 2013. Projections of Full-Fuel-Cycle Energy and Emissions Metrics. LBNL-6025E.

Emissions Monetization Analysis

- Use the most current Social Cost of Carbon (SCC) values developed by interagency process.
  - SCC is intended to be a monetary measure of the incremental damage resulting from greenhouse gas (GHG) emissions, including, but not limited to agricultural productivity loss, human health effects, property damage from rising sea levels, and changes in the ecosystem.
- NPRM used the most recent (2013) U.S. government interagency estimates of the SCC for emissions in 2015, per metric ton avoided (in 2013$):
  - $12.0 (average value from distribution with a 5% discount rate)
  - $40.5 (average value from distribution with a 3% discount rate)
  - $62.4 (average value from distribution with a 2.5% discount rate)
  - $119 (95th-percentile value from distribution with a 3% discount rate)
- Report the SCC in constant dollars as increased over time.
- Monetize the NOx emissions reductions resulting from amended standards.
  - NPRM estimates of monetary value range from $476 to $4,893 per short ton.
  - NPRM calculated monetary benefits using a medium value of $2,684 per short ton.

Proprietary Data

- Data from manufacturer interviews
- Historical shipment data submitted by trade association
- Purchased various market research reports/data and trade literature
- Purchased reference materials (e.g., RS Means)

Backup

Energy and Water Use Analysis (NPRM)

Standard Dishwashers: Annual Energy and Water Use by EL

EL	Annual Energy Use						Annual Water Use (gal/yr)
	Total (kWh/yr)	Water Heating*			Machine + Drying + (kWh/yr)	Standby Power (kWh/yr)	
		Electric (kWh/yr)	Gas (MMBtu/yr)	Oil (MMBtu/yr)			
Baseline	307	177	0.74	0.76	130	0.0	1,075
1	295	150	0.63	0.64	140	4.3	914
2	280	124	0.52	0.53	152	4.3	753
3	234	110	0.46	0.47	120	4.3	667
4	180	79	0.33	0.34	97	4.3	477

Compact Dishwashers: Annual Energy and Water Use by EL

EL	Annual Energy Use						Annual Water Use (gal/yr)
	Total (kWh/yr)	Water Heating*			Machine + Drying + (kWh/yr)	Standby Power (kWh/yr)	
		Electric (kWh/yr)	Gas (MMBtu/yr)	Oil (MMBtu/yr)			
Baseline	222	124	0.52	0.53	78	19.7	753
1	203	110	0.46	0.47	79	14.5	667
2	141	71	0.30	0.30	66	4.3	430

*Water-heating energy use is based on water heater efficiencies of 98% for electric, 80% for gas, and 78% for oil.

Energy and Water Use Analysis (Final Rule)

Standard Dishwashers: Annual Energy and Water Use by EL

EL	Annual Energy Use						Annual Water Use (gal/yr)
	Total (kWh/yr)	Water Heating*			Machine + Drying + (kWh/yr)	Standby Power (kWh/yr)	
		Electric (kWh/yr)	Gas (MMBtu/yr)	Oil (MMBtu/yr)			
Baseline	296	170	0.71	0.73	125	0.0	1,035
1	284	145	0.61	0.62	135	4.3	880
2	260	119	0.50	0.51	137	4.3	725
3	246	106	0.44	0.45	136	4.3	642
4	217	82	0.34	0.35	131	4.3	497

Compact Dishwashers: Annual Energy and Water Use by EL

EL	Annual Energy Use						Annual Water Use (gal/yr)
	Total (kWh/yr)	Water Heating*			Machine + Drying + (kWh/yr)	Standby Power (kWh/yr)	
		Electric (kWh/yr)	Gas (MMBtu/yr)	Oil (MMBtu/yr)			
Baseline	214	119	0.50	0.51	76	19.7	725
1	196	106	0.44	0.45	76	14.6	642
2	125	58	0.25	0.25	63	4.3	352

*Water-heating energy use is based on water heater efficiencies of 98% for electric, 80% for gas, and 78% for oil.

LCC and PBP Analysis: Discount Rates

- Use discount rates to convert streams of annual operating expenses to present value in the LCC Analysis
  - Derived from various types of debt and equity
  - Federal Reserve Board's Survey of Consumer Finances is a source of much of the equity and debt data

Income Group	Discount Rate (%) (NPRM)	Discount Rate (%) (Final Rule)
1	4.85	4.88
2	5.12	5.08
3	4.75	4.67
4	4.04	3.95
5	3.80	3.68
6	3.57	3.49
Overall Average	**4.49**	**4.43**

Dale, Larry L, et al., 2004, An Analysis of Price Determination and Markups in the Air-Conditioning and Heating Equipment Industry. LBNL-52791.

NIA Results: Trial Standard Levels

NPRM

TSL	Standard			Compact		
	Efficiency Level	Annual Energy Use (kWh/year)	Water Use (gal/cycle)	Efficiency Level	Annual Energy Use (kWh/year)	Water Use (gal/cycle)
1	1	295	4.25	Baseline	222	3.50
2	3	234	3.10	1	203	3.10
3	4	180	2.22	2	141	2.00

Final Rule

TSL	Standard			Compact		
	Efficiency Level	Annual Energy Use (kWh/year)	Water Use (gal/cycle)	Efficiency Level	Annual Energy Use (kWh/year)	Water Use (gal/cycle)
1	3	255	3.10	1	203	3.10
2	3	255	3.10	2	130	1.70

NIA Results

Category	NPRM			Final Rule	
	TSL 1	TSL 2	TSL 3	TSL 1	TSL 2
National Full-Fuel Cycle Energy and Water Savings over 30 years of shipments (quads and trillion gallons)					
	0.01 / 0.03	1.06 / 0.24	2.53 / 0.99	0.49 / 0.42	0.50 / 0.43
National Full-Fuel Cycle Energy and Water Savings over 9 years of shipments (quads and trillion gallons)					
	0.00 / 0.01	0.28 / 0.05	0.72 / 0.27	0.13 / 0.11	0.14 / 0.11
NPV of Consumer Benefits (2013$/2015$ billion, 30 years of shipments)					
3% discount rate	0.15	2.14	15.7	2.08	2.21
7% discount rate	0.05	0.23	5.56	0.33	0.37
NPV of Consumer Benefits (2013$/2015$ billion, 9 years of shipments)					
3% discount rate	0.06	0.13	4.96	0.49	0.53
7% discount rate	0.03	(0.14)	2.43	0.03	0.05

Note: Parentheses indicate negative values.