CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

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CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

8.1 INTRODUCTION

This chapter describes the Department of Energy (DOE)'s methodology for analyzing the economic impacts of possible energy efficiency standards on individual consumers. Impacts include a change in operating expense (usually decreased) and a change in purchase price (usually increased). This chapter describes three metrics DOE used in the consumer analysis to determine the effect of standards on individual consumers:

- **Life-cycle cost** (LCC) is the total consumer expense over the life of an appliance, including purchase expense and operating costs (including energy expenditures). DOE discounts future operating costs to the time of purchase and sums them over the lifetime of the product.

- **Payback period** (PBP) measures the amount of time it takes customers to recover the assumed higher purchase price of more energy-efficient products through lower operating costs.

- **Rebuttable payback period** is a special case of the PBP. Where LCC and PBP are estimated over a range of inputs that reflect real-world conditions, rebuttable payback period is based on laboratory conditions, specifically those representative of the DOE test procedure.

Inputs to the LCC and PBP are discussed in sections 8.2 and 8.3, respectively, of this chapter. Results of the LCC and PBP are presented in section 8.4. The rebuttable PBP is discussed in section 8.5. Key variables and calculations are presented for each metric. DOE performed the calculations discussed here using a series of Microsoft Excel spreadsheets, which are accessible on the Internet (http://www.eere.energy.gov/buildings/appliance_standards/). Details and instructions for using the spreadsheets are discussed in appendix 8A.

8.1.1 General Approach for Life-Cycle Cost and Payback Period Analysis

Recognizing that several inputs to the analysis of consumer LCC and PBP are either variable or uncertain, DOE used Monte Carlo simulation and probability distributions to define inputs when appropriate. Appendix 8B provides a detailed explanation of Monte Carlo simulation and the use of probability distributions. DOE developed LCC and PBP spreadsheet models that incorporate both Monte Carlo simulation and probability distributions by using Microsoft Excel spreadsheets combined with Crystal Ball (a commercially available add-in program).

In addition to using probability distributions to characterize several of the inputs to the analysis, DOE developed a sample of individual households that use dishwashers, which includes 2,480 household records. By developing household samples, DOE was able to perform the LCC and PBP calculations for each household to account for the variability in energy and water consumption and/or energy price associated with each household. As described in chapter 7, DOE used the DOE Energy Information Administration (EIA)'s 2005 Residential Energy Consumption Survey (RECS) to develop household samples for standard and compact dishwashers.[1] The 2005 RECS is a national sample survey of housing units that collects statistical information on the consumption of and expenditures for energy in housing units along with data on energy-related characteristics of the housing units and occupants. The 2005 RECS, which represents 4,382 housing units, was constructed by EIA to be a national representation of the household population in the U.S. Although the standard error of the sub-samples is three times the size of the entire 2005 RECS, it is still less than five percent. DOE believes a standard error of less than five percent is still small enough to yield meaningful results. Therefore, DOE believes the results generated from the household samples for dishwashers are representative of U.S. households using these appliances.

DOE used RECS to establish the variability in annual energy use, energy pricing, annual water use, and water pricing. By using RECS, DOE was able to assign a unique annual energy use and/or energy price to each household in the sample. The large number of households considered in the LCC and PBP analysis resulted in a large range of annual energy and water use and/or prices (the actual ranges of energy consumption were presented and discussed in chapter 7). The variability in annual energy and water use and pricing across all households contributes to the range of LCCs and PBPs calculated for each standard level. As described later in this chapter, DOE characterized the variability and uncertainty in energy and water prices through regional differences.

DOE displays the LCC and PBP results as distributions of impacts compared to the base case. Results are presented at the end of this chapter and are based on 10,000 samples per Monte Carlo simulation run. To illustrate the implications of the analysis, DOE generated a frequency chart depicting the variation in LCC and PBP for each standard level considered.

8.1.2 Overview of Life-Cycle Cost and Payback Period Inputs

The LCC is the total consumer expense over the life of the product, including purchase expense and operating expense (including energy and water expenditures). DOE discounts future operating expenses to the time of purchase and sums them over the lifetime of the product. The PBP is the change in purchase expense due to an increased efficiency standard divided by the change in annual operating cost that results from the standard. It represents the number of years it will take the customer to recover the increased purchase expense through decreased operating expenses.

DOE categorizes inputs to the LCC and PBP analysis as follows: (1) inputs for establishing the total installed cost, including the purchase price, and (2) inputs for calculating the operating cost.

The primary inputs for establishing the total installed cost are:

- *Baseline manufacturer cost* is the cost incurred by the manufacturer to produce products meeting existing minimum efficiency standards, or the baseline product.

- *Standard-level manufacturer cost increases* represent the change in manufacturer cost associated with producing products to meet a particular standard level.

- *Markups and sales tax* are costs associated with converting the manufacturer cost to a consumer product price. The markups and sale tax are described in detail in Chapter 6, Markups for Equipment Price Determination.

- *Installation cost* is the cost to the consumer of installing the product after purchase, including costs for labor, overhead, and any miscellaneous materials and parts. Thus, the total installed cost equals the consumer product price plus the installation cost.

The primary inputs for calculating the operating cost are:

- *Product energy and water consumption* quantify the energy and water use associated with operating the product. Chapter 7, Energy and Water Use Analysis, details how DOE used various data sources to determine the product energy and water consumption of standard and compact dishwashers.

- *Product efficiency* dictates the energy and water consumption associated with a standard-level product (i.e., a product having an efficiency greater than a baseline product). Chapter 7 details how energy and water consumption change with increasing product efficiency.

- *Energy and water prices* are the prices consumers pay for energy (i.e., electricity, gas, or oil) and water. DOE determined current energy prices based on data from the DOE- EIA and *Natural Gas Monthly* (see section 8.2.2.2). DOE determined water prices based on data from the American Water Works Association (AWWA) and the Raftelis Financial Consultants (see section 8.2.2.2).[2]

- *Energy and water price trends*: DOE used the reference case in EIA's *Annual Energy Outlook 2011* (*AEO2011*) to forecast future energy prices for the results presented in this chapter. DOE used the Bureau of Labor Statistics' consumer price index (CPI) data specific to water and sewage services to forecast future water prices.

- *Repair and maintenance costs*: Repair costs are associated with repairing or replacing components that have failed. Maintenance costs are associated with maintaining the operation of the product. Section 8.2.2.4 details DOE's method for estimating repair and maintenance costs.

- *Lifetime* is the age at which the product is retired from service. Section 8.2.3 describes the distribution DOE developed for product lifetimes.

- *Discount rate* is the rate at which DOE discounted future expenditures to establish their present value.

Figure 8.1.1 graphically depicts the relationships between the installed cost and operating cost inputs used to calculate the LCC and PBP. In the figure, the yellow boxes indicate the inputs, the green boxes indicate intermediate outputs, and the blue boxes indicate the final outputs (the LCC and PBP).

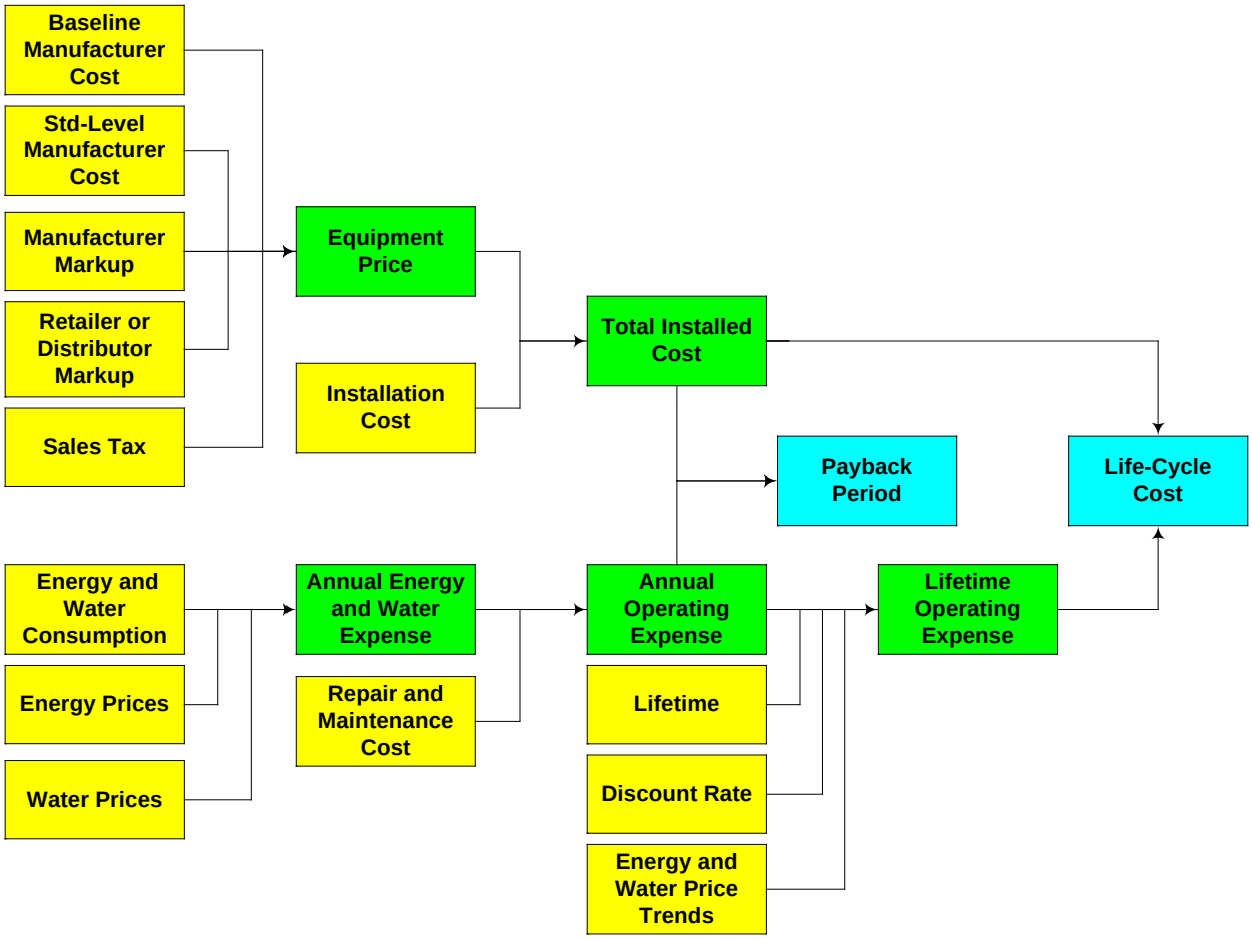

Figure 8.1.1 Flow Diagram for the Determination of LCC and PBP

Table 8.1.1 summarizes the input values that DOE used to calculate the LCC and PBP for standard and compact dishwashers. Inputs to calculate the total installed cost and operating cost include the lifetime, discount rate, and energy and water price trends. DOE characterized all of the total cost inputs with single-point values, but characterized several of the operating cost inputs with probability distributions that capture the input's uncertainty and/or variability. For those inputs characterized with probability distributions, the values provided in the following

tables are the average or typical values. Table 8.1.1 also includes the section of this technical support document (TSD) that contains more detailed information on the inputs.

Table 8.1.1 Dishwashers: Summary of LCC and PBP Inputs

Input	Product Class	Average or Typical Value	Characterization	TSD Section Reference
Total Installed Cost Inputs				
Baseline Manufacturer Cost	Standard Compact	355 AEU = $190.98 260 AEU = $185.72	Single-Point Value	8.2.1.1
Standard-Level Manufacturer Cost Increase	Standard	324 AEU = $18.27 307 AEU = $31.82 295 AEU = $69.23 234 AEU = $75.18 180 AEU = $82.95	Single-Point Value	5.5.1
	Compact	222 AEU = $1.00 154 AEU = $12.11		
Manufacturer Markup	Both	1.24	Single-Point Value	6.2
Retailer Markup	Both	Baseline = 1.45 Incremental = 1.17	Single-Point Value	6.3
Sales Tax	Both	7.17% (average)	Variable based on location	6.4
Installation Cost	Both	$303.00	Single-Point Value	8.2.1.5
Operating Cost Inputs				
Usage	Both	215 cycles/year	Variability determined from household sample. Usage ranges from 4 to 612 cycles/year	7.4
Annual Energy Use*	Standard Compact	Baseline use** = 211 kWh Baseline use** = 160 kWh	Variability based on usage	7.3
Annual Water Use	Standard Compact	Baseline use** = 1.40 10^3 gallon Baseline use** = 0.97 10^3 gallon	Variability based on usage	7.3
Energy Prices	Both	Electricity = 0.12 ¢/kWh Gas = 14.35 $/MMBtu Oil = 17.09 $/MMBtu	Variable based on location	8.2.2.2
Water and Wastewater	Both	Water = 3.30 $/$10^3$ gallon Wastewater = 3.87 $/$10^3$	Variable based on location	8.2.2.2

Input	Product Class	Average or Typical Value	Characterization	TSD Section Reference
Prices		gallon		
Repair and Maintenance Costs	Both	Not included	No appreciable difference between baseline and efficiency level repair costs	8.2.2.4
Lifetime	Both	15.4 years	Weibull distribution	8.2.3
Discount Rate	Both	4.91%	Custom distribution	8.2.4
Energy Price Trend	Both	AEO 2011	AEO reference case	8.2.2.3
Water and Wastewater Price Trend	Both	Extrapolated based on growth in 1970–2009 for CPI for water and sewerage.	Single forecast	8.2.2.3

* Annual use based on electric water heating.

** Annual use provided for baseline product only. Annual use decreases with increased product efficiency.

8.2 INPUTS TO LIFE-CYCLE COST ANALYSIS

Life-cycle cost is the total customer expense over the life of an appliance, including purchase price and operating costs (including energy and water costs). DOE discounts future operating costs to the time of purchase and sums them over the lifetime of the product. DOE defines LCC by the following equation:

$$LCC = IC + \sum_{t=1}^{N} \frac{OC_t}{(1+r)^t}$$

Where:

LCC = life-cycle cost in dollars,
IC = total installed cost in dollars,
∑ = sum over the lifetime, from year 1 to year N,
N = lifetime of appliance in years,
OC = operating cost in dollars,
r = discount rate, and
t = year for which operating cost is being determined.

Because DOE gathered most of its data for the LCC and PBP analysis in 2010, DOE expresses dollar values in 2010$. The following sections discuss total installed cost, operating cost, lifetime, and discount rate.

8.2.1 Total Installed Cost Inputs

DOE defines the total installed cost using the following equation:

$$IC = EQP + INST$$

Where:

EQP = Product price (i.e., price the consumer pays for the product, including taxes), expressed in dollars, and
INST = Installation cost (i.e., the cost to the consumer to install the product, including labor and materials), also in dollars.

The product price is based on how the consumer purchases the product. As discussed in chapter 6, DOE defined markups and sales taxes for converting manufacturing costs into consumer product prices. The inputs for the total installed cost are:

- *Baseline manufacturer cost* is the cost incurred by the manufacturer to produce a product meeting existing minimum efficiency standards.
- *Standard-level manufacturer cost increases* are the change in manufacturer cost associated with producing a product at a standard level.
- *Manufacturer and retailer markups and sales tax* convert the manufacturer cost to a consumer product price.
- *Installation cost* is the cost to the consumer of installing the product and represents all costs required to install the product other than the marked-up consumer product price. The installation cost includes labor, overhead, and any miscellaneous materials and parts.

Thus, the total installed cost equals the consumer product price plus the installation cost. DOE calculated the total installed cost for baseline products based on the following equation:

$$\begin{aligned} IC_{BASE} &= EQP_{BASE} + INST_{BASE} \\ &= COST_{MFG} \times MU_{OVERALL\_BASE} + INST_{BASE} \end{aligned}$$

Where:

IC_{BASE} = total installed cost for baseline product,
EQP_{BASE} = consumer product price for baseline product,
$INST_{BASE}$ = installation cost for baseline product,
$COST_{MFG}$ = manufacturer cost for baseline product, and
$MU_{OVERALL\_BASE}$ = overall baseline markup (product of manufacturer markup, baseline retailer markup, and sales tax).

DOE calculated the total installed cost for standard-level products based on the following equation:

$$
\begin{aligned}
IC_{STD} &= EQP_{STD} + INST_{STD} \\
&= \left(EQP_{BASE} + \Delta EQP_{STD}\right) + \left(INST_{BASE} + \Delta INST_{STD}\right) \\
&= \left(EQP_{BASE} + INST_{BASE}\right) + \left(\Delta EQP_{STD} + \Delta INST_{STD}\right) \\
&= IC_{BASE} + \left(\Delta COST_{MFG} \times MU_{OVERALL\_INCR} + \Delta INST_{STD}\right)
\end{aligned}
$$

Where:

IC_{STD} =	standard-level total installed cost,
EQP_{STD} =	consumer product price for standard-level models,
$INST_{STD}$ =	standard-level installation cost,
EQP_{BASE} =	consumer product price for baseline models,
ΔEQP_{STD} =	change in product price for standard-level models,
$INST_{BASE}$ =	baseline installation cost,
$\Delta INST_{STD}$ =	change in installation cost for standard-level models,
IC_{BASE} =	baseline total installed cost,
$\Delta COST_{MFG}$ =	change in manufacturer cost for standard-level models, and
$MU_{OVERALL\_INCR}$ =	incremental overall markup (product of manufacturer markup, incremental retailer or distributor markup, and sales tax).

The remainder of this section provides information about each of the above input variables that DOE used to calculate the total installed cost for standard and compact residential dishwashers.

8.2.1.1 Forecasting Future Product Prices

Examination of historical price data for certain appliances and products that have been subject to energy conservation standards indicates that the assumption of constant real prices and costs may, in many cases, overestimate long-term trends in appliance and product prices. Economic literature and historical data suggest that the real costs of these products may in fact trend downward over time according to "learning" or "experience" curves. On February 22, 2011, DOE published a notice of data availability (NODA, 76 FR 9696) stating that DOE may consider improving regulatory analysis by addressing product price trends. In the NODA, DOE proposed that when sufficiently long-term data are available on the cost or price trends for a given product, it would analyze the available data to forecast future trends.

For the default price trend for this final rule, DOE estimated an experience rate for residential dishwashers based on an analysis of long-term historical data. DOE derived a dishwasher price index from 1988 to 2010 using Producer Price Index (PPI) data for miscellaneous household appliances from the Bureau of Labor Statistics' (BLS). (PPI data specific to residential dishwashers were not available.) An inflation-adjusted price index was calculated using the GDP price deflator for the same years. This proxy for historic price data was then regressed on the quantity of dishwashers produced, based on a corresponding series for total shipments of dishwashers.

To calculate an experience rate, a least-squares power-law fit was performed on the dishwasher price index versus cumulative shipments. DOE then derived a price factor index, with the price in 2010 equal to 1, to forecast prices in the year of compliance for amended energy conservation standards in the LCC and PBP analysis, and for the NIA, for each subsequent year through 2047. The index value in each year is a function of the experience rate and the cumulative production through that year. To derive the latter, DOE used projected shipments from the base-case projections made for the NIA (see section IV.G.1 of this notice). The average annual rate of price decline in the default case is 1.27 percent. DOE's forecast of product prices for dishwashers in the LCC and PBP analysis is described further in appendix 8C.

8.2.1.2 Baseline Manufacturer Selling Price

DOE used data from AHAM to develop the baseline manufacturer selling prices for standard-sized and compact dishwashers.[3] Based on a manufacturer markup of 1.24 for all dishwashers (see section 6.2 of chapter 6), DOE arrived at a baseline manufacturer selling price (MSP) of $190.98 for standard-size dishwashers and $185.72 for compact dishwashers. Table 8.2.1 presents the baseline manufacturer costs along with the associated baseline annual energy use for the product classes of residential dishwashers.

Table 8.2.1 Dishwashers: Baseline Manufacturer Selling Price

Product Class	Baseline Annual Energy Use kWh/year	Baseline Water Use gallons/cycle	Baseline Manufacturer Cost 2010$
Standard	355	6.50	190.98
Compact	260	4.50	185.72

8.2.1.3 Increases in Manufacturer Costs

DOE used cost data submitted by AHAM, along with a reverse engineering analysis, to develop manufacturer cost increases associated with increases in standard levels for residential dishwashers. Refer to Chapter 5, Engineering Analysis, for details. Table 8.2.2 and Table 8.2.3 present the standard-level manufacturer cost increases and associated annual energy use for the product classes.

Table 8.2.2 Standard-Sized Dishwashers: Standard-Level Manufacturer Cost Increases

Efficiency Level	Annual Energy Use kWh/year	Water Use gallons/cycle	Standard-Level Manufacturer Cost Increases 2010$
Baseline	355	6.50	--
1	324	5.80	18.27
2	307	5.00	31.82
3	295	4.25	69.23
4	234	3.80	75.18
5	180	1.60	82.95

Table 8.2.3 Compact Dishwashers: Standard-Level Manufacturer Cost Increases

Efficiency Level	Annual Energy Use kWh/year	Water Use gallons/cycle	Standard-Level Manufacturer Cost Increases 2010$
Baseline	260	4.50	--
1	222	3.50	1.00
2	154	2.10	12.11

8.2.1.4 Overall Markup

The overall markup is the value determined by multiplying the manufacturer and retailer markups and the sales tax together to arrive at a single markup value. Table 8.2.4shows the overall baseline and incremental markups for dishwashers. Refer to Chapter 6, Markups for Equipment Price Determination, for details.

Table 8.2.4 Dishwashers: Overall Markups

Markup	Baseline	Incremental
Manufacturer	1.24	
Retailer	1.45	1.17
Sales Tax	1.0717	
Overall	**1.93**	**1.55**

8.2.1.5 Installation Cost

DOE derived baseline installation costs for dishwashers from data in the *RS Means Plumbing Cost Data, 2010*,[4] which provides estimates on the labor required to install residential dishwashers. Table 8.2.5 summarizes the nationally representative average bare costs and installation costs of a four-or-more-cycle dishwasher. DOE determined that installation costs would not be impacted with increased standard levels.

Table 8.2.5 Dishwashers: Baseline Installation Costs

Installation Type	Bare Costs 2010$			Including Overhead & Profit 2010$		
	Material	Labor	Total	Total	Material*	Labor**
Average	370	202	572	710	407	303
					Average 2010$	303

* Material costs including O&P equal bare costs plus 10% profit.

** DOE derived labor costs including O&P by subtracting material with O&P from total with O&P.

Source: RS Means, *Plumbing Cost Data, 2010.*

8.2.1.6 Total Installed Cost

The total installed cost is the sum of the consumer product price and the installation cost. Recall section 8.2.1 for the equations DOE used to calculate the total installed cost for baseline and standard-level products.

Table 8.2.6 and Table 8.2.7 present the consumer product price, installation cost, and total installed cost for standard-sized and compact dishwashers, respectively, at the baseline level and each standard level.

Table 8.2.6 Standard-Sized Dishwashers: Consumer Product Prices, Installation Costs, and Total Installed Costs

Efficiency Level	Annual Energy Use kWh/year	Water Use gallons/cycle	Product Price 2010$	Installation Cost 2010$	Total Installed Cost 2010$
Baseline	355	6.50	327.45	303.00	630.45
1	324	5.80	352.73	303.00	655.73
2	307	5.00	371.47	303.00	674.47
3	295	4.25	423.23	303.00	726.23
4	234	3.80	431.47	303.00	734.47
5	180	1.60	442.22	303.00	745.22

Table 8.2.7 Compact Dishwashers: Consumer Product Prices, Installation Costs, and Total Installed Costs

Efficiency Level	Annual Energy Use kWh/year	Water Use gallons/cycle	Product Price 2010$	Installation Cost 2010$	Total Installed Cost 2010$
Baseline	260	4.50	318.43	303.00	621.43
1	222	3.50	319.82	303.00	622.82
2	154	2.10	335.19	303.00	638.19

8.2.2 Operating Cost Inputs

DOE uses the following equation to define the operating cost of an appliance:

$$OC = EC + WC + RC + MC$$

Where:

OC = operating cost,
EC = energy cost associated with operating the product,
WC = water cost associated with operating the product,
RC = repair costs associated with component failure, and
MC = service costs for maintaining product operation.

The inputs for calculating operating costs are also necessary to determine lifetime operating costs, which include the energy and water price trends, product lifetime, discount rate, and effective date of the standard.

- *Annual energy consumption* is the site energy use associated with operating the product.
- *Annual water consumption* is the site water use associated with operating the product. Both the annual energy and water consumption vary with the product efficiency. That is, the energy and water consumption associated with standard-level products (i.e., products having efficiencies greater than baseline product) are less than the consumptions associated with baseline products.
- *Energy and water prices* are the prices paid by consumers for energy (i.e., electricity, gas, or oil) and water. Multiplying the annual energy and water consumption by the energy and water prices yields the annual energy cost and water cost, respectively.
- *Repair costs* are associated with repairing or replacing components that have failed.
- *Maintenance costs* are associated with maintaining the operation of the product.
- DOE used *energy and water price trends* to forecast energy and water prices into the future and, along with the product lifetime and discount rate, to establish the lifetime energy and water costs.
- *Product lifetime* is the age at which the product is retired from service.
- The *discount rate* is the rate at which DOE discounted future expenditures to establish their present value.

DOE calculated the operating cost for baseline products based on the following equation:

$$\begin{aligned} OC_{BASE} &= EC_{BASE} + WC_{BASE} + RC_{BASE} + MC_{BASE} \\ &= AEC_{BASE} \times PRICE_{ENERGY} + AWC_{BASE} \times PRICE_{WATER} + RC_{BASE} + MC_{BASE} \end{aligned}$$

Where:

OC_{BASE} = operating cost for the baseline product,
EC_{BASE} = energy cost associated with operating the baseline product,

WC_{BASE} = water cost associated with operating the baseline product,
RC_{BASE} = repair cost associated with component failure for the baseline product,
MC_{BASE} = service cost for maintaining baseline product operation,
AEC_{BASE} = annual energy consumption for baseline product,
$PRICE_{ENERGY}$ = energy price,
AWC_{BASE} = annual water consumption for baseline product, and
$PRICE_{WATER}$ = water price.

DOE calculated the operating cost for standard-level products based on the following equation:

$$\begin{aligned} OC_{STD} &= EC_{STD} + WC_{STD} + RC_{STD} + MC_{STD} \\ &= AEC_{STD} \times PRICE_{ENERGY} + AWC_{STD} \times PRICE_{WATER} + RC_{STD} + MC_{STD} \\ &= \left(AEC_{BASE} - \Delta AEC_{STD}\right) \times PRICE_{ENERGY} + \left(AWC_{BASE} - \Delta AWC_{STD}\right) \times PRICE_{WATER} \\ &\quad + \left(RC_{BASE} + \Delta RC_{STD}\right) + \left(MC_{BASE} + \Delta MC_{STD}\right) \end{aligned}$$

Where:

OC_{STD} = operating cost for standard-level product,
EC_{STD} = energy cost associated with operating standard-level product,
WC_{STD} = water cost associated with operating standard-level product,
RC_{STD} = repair cost associated with component failure for standard-level product,
MC_{STD} = service cost for maintaining standard-level product operation,
AEC_{STD} = annual energy consumption for standard-level product,
$PRICE_{ENERGY}$ = energy price,
AWC_{STD} = annual water consumption for standard-level product,
$PRICE_{WATER}$ = water price,
ΔAEC_{STD} = change in annual energy consumption caused by standard-level product,
ΔAWC_{STD} = change in annual water consumption caused by standard-level product,
ΔRC_{STD} = change in repair cost caused by standard-level product, and
ΔMC_{STD} = change in maintenance cost caused by standard-level product.

The remainder of this section provides information about each of the above input variables that DOE used to calculate the operating costs for dishwashers.

8.2.2.1 Annual Energy and Water Consumption

Chapter 7, Energy and Water Use Analysis, details how DOE determined the annual energy and water consumption for baseline and standard-level products.

As described in section 7.4 of chapter 7 and section 8.1.1, DOE developed a sample of individual households that use one of the product classes of dishwashers. By developing household samples, DOE was able to perform the LCC and PBP calculations for each household to account for the variability in the usage and price of both energy and water associated with

each household. DOE used EIA's 2005 RECS to develop the household samples and, in turn, to establish the variability in both annual energy and water consumption and energy and water pricing. Refer to chapter 6 to review the variability of annual energy consumption for dishwashers.

The tables presented below are based on the energy and water use analysis described in chapter 7. Keep in mind that the annual energy and water consumption values in the tables below are averages. DOE captured the variability in energy and water consumption in the LCC and PBP analysis.

Table 8.2.8 and Table 8.2.9 provide the average annual energy and water consumption by efficiency level for standard-sized and compact dishwashers, respectively. These tables are similar to those in section 7.3 of chapter 7 with the exception that, in Table 8.2.8 and Table 8.2.9, the electric, gas, and oil water-heating consumption takes into account the percentage of households in the United States that use electric, gas, and oil water heaters, respectively. In others words, the electric, gas, and oil water heating consumption is weighted by the share of households that use electric, gas, and oil water heaters. Based on data from the RECS, 37.2 percent of households use electric water heaters, 58.9 percent use gas, and 3.9 percent use oil.

Table 8.2.8 Standard Dishwashers: Annual Energy and Water Use by Efficiency Level

Efficiency Level	Annual Energy Use	Annual Energy Use Water Heating*			Annual Water Use
		Electric kWh/year	Gas MMBtu/year	Oil MMBtu/year	1,000 gal/year
Baseline	355	211	0.62	0.04	1.40
1	324	195	0.55	0.04	1.25
2	307	196	0.47	0.03	1.08
3	295	201	0.40	0.03	0.92
4	234	150	0.36	0.02	0.82
5	180	145	0.15	0.01	0.35

* Electric, gas, and oil water heating based on water heater efficiencies of 100% for electric, 75% for gas, 75% for oil.

Table 8.2.9 Compact Dishwashers: Annual Energy and Water Use by Efficiency Level

Efficiency Level	Annual Energy Use	Annual Energy Use Water Heating*			Annual Water Use
		Electric kWh/year	Gas MMBtu/year	Oil MMBtu/year	1,000 gal/year
Baseline	260	160	0.43	0.03	0.97
1	222	144	0.33	0.02	0.75
2	154	107	0.20	0.01	0.45

* Electric, gas, and oil water heating based on water heater efficiencies of 100% for electric, 75% for gas, 75% for oil.

8.2.2.2 Energy and Water Prices

DOE used probability distributions to characterize the regional variability in energy and water prices. DOE developed the probability associated with each regional energy and water price based on the population weight of each region. DOE's method for deriving energy and water prices is described below.

Electricity Prices

DOE derived average energy prices from data that are published annually based on EIA Form 861. Those data include, for every utility that serves final consumers, annual electricity sales in kilowatt-hours; revenues from electricity sales; and number of customers in the residential, commercial, and industrial sectors. DOE calculated prices for each of 13 geographic areas: the nine U.S. Census divisions plus four large states (New York, Florida, Texas, and California). For Census divisions that contain one of the large states, DOE removed the data for that state from the calculation of the regional average. The Pacific region average does not include California, for example, and the West South Central does not include Texas.

The calculation of average residential electricity price proceeded in two steps.

1. For each utility, DOE estimated an average residential price by dividing residential revenues by residential sales.
2. DOE calculated a regional average price, weighting each utility that serves residences in a region by the number of residential customers served in that region.

Table 8.2.10 shows results for the 13 geographic regions.

Table 8.2.10 Average Residential Electricity Prices

Geographic Area	Average Price 2010$/kWh
New England	0.178
Middle Atlantic (excluding New York)	0.139
East North Central	0.113
West North Central	0.094
South Atlantic (excluding Florida)	0.111
East South Central	0.098
West South Central (excluding Texas)	0.087
Mountain	0.104
Pacific (excluding California)	0.102
New York	0.188
Florida	0.151
Texas	0.126
California	0.126

Source: EIA Form 861 for 2009.

Natural Gas Prices

DOE obtained data for calculating regional prices of natural gas from the EIA publication, *Natural Gas Navigator*.[5] This publication presents monthly volumes of natural gas deliveries and average prices by state for residential, commercial, and industrial customers. The Department used the complete annual data for 2010 to calculate an average annual price for each geographic area. The calculation of average prices proceeded in two steps.

1. For each state, DOE calculated the annual residential price of natural gas using a simple average of data.
2. DOE then calculated a regional price, weighting each state in a region by its population.

The method used to calculate natural gas prices differs from that used to calculate electricity prices, because the EIA does not provide consumer- or utility-level data on gas consumption and prices. The prices in Table 8.2.11 are in dollars per million BTU ($/MMBtu).

Table 8.2.11 Average Residential Natural Gas Prices

Geographic Area	Average Price 2010$/MMBtu
New England	15.68
Middle Atlantic (excluding New York)	14.26
East North Central	12.47
West North Central	12.07
South Atlantic (excluding Florida)	17.14
East South Central	14.00
West South Central (excluding Texas)	13.89
Mountain	11.41
Pacific (excluding California)	13.14
New York	15.69
Florida	10.00
Texas	12.86
California	19.93

Source: EIA *Natural Gas Monthly*, 2010

Because DOE conducted the LCC and PBP analysis in 2010, all natural gas prices are in 2010$.

Residential Oil Prices

DOE collected 2009 oil prices from EIA's Petroleum Navigator,[6] which includes monthly oil prices for residential, commercial, industrial, and transportation consumers by Petroleum Administration for Defense Districts (PADD). The first four PADD follow the U.S. Census divisions. However, Arizona is not included in the PADD for the Pacific Region and New Mexico is excluded altogether. In addition, data was not provided for the East South Central region, West South Central region, Florida, Texas, and California, so national averages were used for these regions. DOE weighted the average residential oil prices for each PADD by the amount of oil consumed in each PADD. DOE then transformed the data in units of cents/gallon to $/MMBtu. Finally, the prices were aggregated and averaged by nine geographic areas (Table 8.2.12). The EIA oil price data do not include taxes, so DOE determined the average tax rate for the four Census regions (Northeast, South, Midwest, and West)[7] and applied it to the annual average data.

Table 8.2.12 Average Monthly Residential Oil Prices in 2009

Geographic Area	Average Price 2010$/MMBtu
New England	18.64
Middle Atlantic (excluding New York)	18.35
East North Central	16.41
West North Central	16.46
South Atlantic (excluding Florida)	17.95
East South Central	16.09
West South Central (excluding Texas)	14.54
Mountain	16.14
Pacific (excluding California)	18.21
New York	19.08
Florida	18.43
Texas	14.65
California	17.51

*National average
**Pacific Division average
***South Atlantic Division average

Water Prices

DOE obtained data on water prices for 2010 from the *Water and Wastewater Rate Survey* conducted by Raftelis Financial Consultants and the American Water Works Association.[2] The survey covers approximately 308 water utilities and 228 wastewater utilities, analyzing each industry (water and wastewater) separately. The water survey includes, for each utility, the cost to consumers of a given volume of water. The total consumer cost is divided into fixed and volumetric charges. DOE's calculation of water prices uses only volumetric charges, because only those charges would be affected by a change in water consumption. Including the fixed charge in the average would lead to a slightly higher water price.

For wastewater utilities, the data format is similar, except that the price represents the cost to treat a given volume of wastewater. A sample of 308 or 228 utilities is too small to calculate regional prices for all U.S. Census divisions and large states (for comparison, data from EIA Form 861 cover more than 3,000 utilities). Therefore, DOE calculated regional costs for wastewater service at the level of Census regions only (Northeast, South, Midwest, and West). The calculation of average prices per unit volume proceeds in three steps.

1. For each water or wastewater utility, DOE calculated the price per unit volume by dividing the total volumetric cost by the volume delivered.
2. DOE calculated a state-level average price by weighting each utility in a given state by the number of residential customers it serves.

3. DOE calculated a regional average by combining the state-level averages, weighting each by the state's population. This third step helps reduce any bias in the sample that may result from the relative under-sampling of large states.

Table 8.2.13 presents the results of the calculation of costs for water and wastewater service. The price units in the table are 2010 dollars per thousand gallons (/tg).

Table 8.2.13 Average Water and Wastewater Prices per Unit Volume

Census Region	Water 2010$/tg	Wastewater 2010$/tg
Northeast	4.07	3.53
Midwest	2.21	2.77
South	3.01	4.68
West	4.06	3.96
National Average	3.30	3.87

8.2.2.3 Energy and Water Price Trends

DOE used EIA price forecasts to estimate the trends in natural gas, oil, and electricity prices. To arrive at prices in future years, it multiplied the average prices described in the preceding section by the forecast of annual average price changes in EIA's *AEO 2011*.[8] To estimate the trend after 2030, DOE followed past guidelines provided to the Federal Energy Management Program (FEMP) by EIA and used the average rate of change during 2020–2035.

The Department calculated LCC and PBP using three separate projections from *AEO 2011*: Reference, Low Economic Growth, and High Economic Growth. These three cases reflect the uncertainty of economic growth in the forecast period. The high and low growth cases show the projected effects of alternative growth assumptions on energy markets. Figure 8.2.1 shows the residential electricity price trend based on the three *AEO 2011* projections. For the LCC results presented in section 8.4, DOE used only the energy price forecasts from the AEO Reference case.

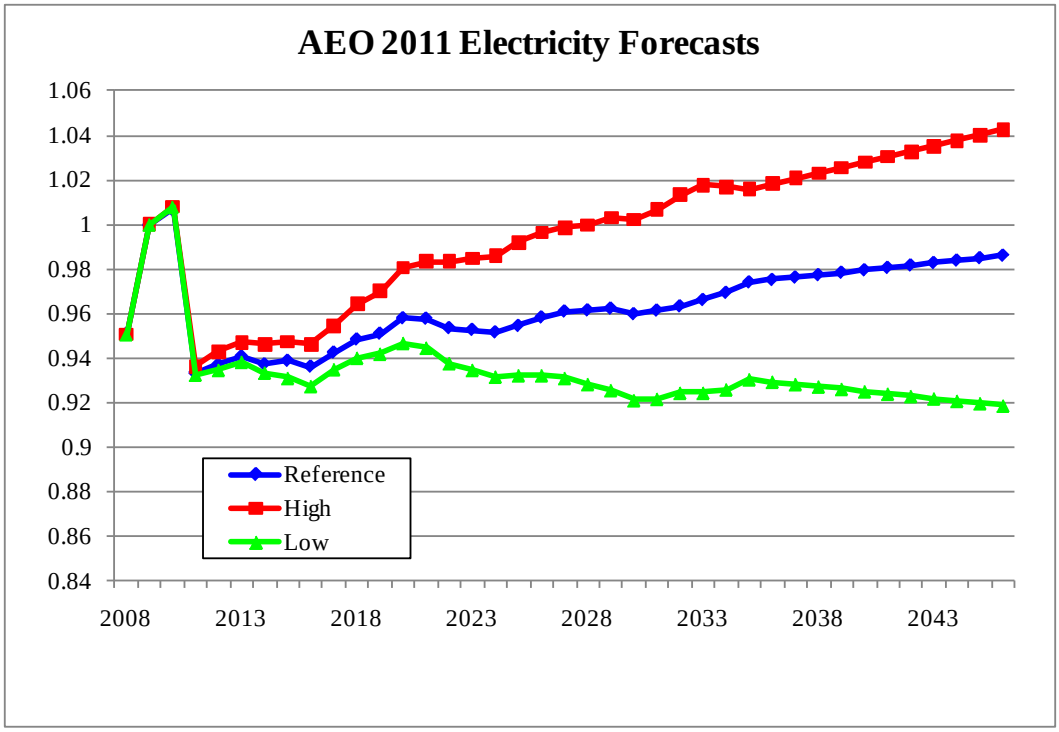

Figure 8.2.1 Electricity Price Trends

To estimate the future trend for water and wastewater prices, DOE used data on the historic trend in the national water price index (U.S. city average) from 1970 through 2005,[9] combined with the all-products CPI for this same period. It extrapolated a future trend based on the linear inflation-adjusted growth during the 1970–2005 period. Figure 8.2.2 shows the projected inflation-adjusted water price trend. DOE used this fit to forecast water and wastewater prices for residential dishwashers.

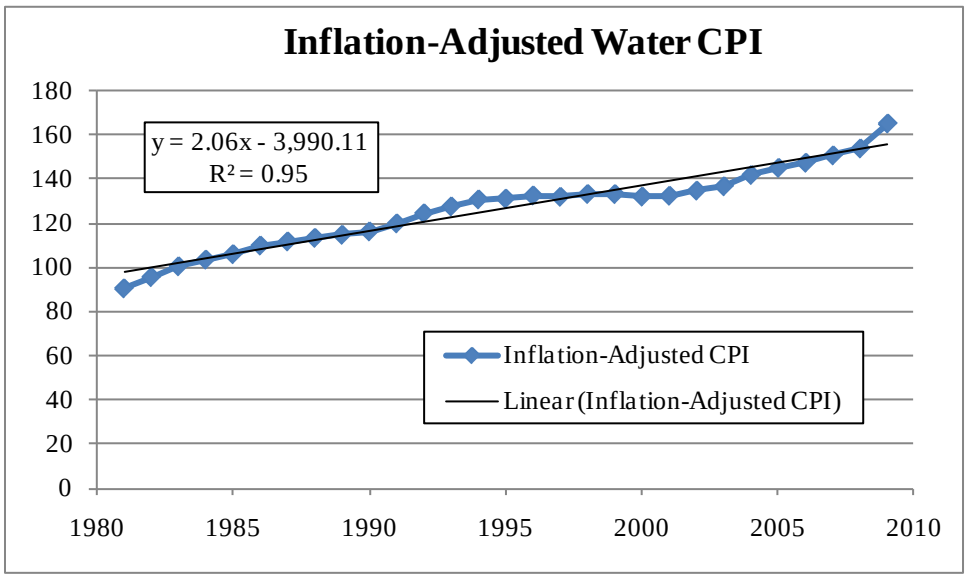

Figure 8.2.2 Inflation-Adjusted Water Price Trend

8.2.2.4 Repair and Maintenance Costs

Typically, small incremental changes in product efficiency produce no, or only slight, changes in repair and maintenance costs over baseline products. However, products having significantly higher efficiencies, compared to baseline products, are more likely to incur higher repair and maintenance costs because their increased complexity and higher part count typically increases the cumulative probability of failure. DOE requested that manufacturers and other stakeholders assist in developing appropriate repair and maintenance, but it did not receive any input. Thus DOE did not include any changes in repair and maintenance costs for products more efficient than baseline products.

8.2.3 Product Lifetimes

RECS records the presence of various appliances in each household and places the age of each appliance into bins comprising several years. Data from the U.S. Census's *American Housing Survey* (AHS),[10] which surveys all housing including vacant and second homes, enabled DOE to adjust the RECS data to reflect some appliance use outside of primary residences. By combining the results of both surveys with the known history of appliance shipments (collected from *Appliance* magazine or directly from manufacturer trade associations), DOE estimated the percentage of appliances of a given age still in operation. This survival function, which DOE assumed has the form of a cumulative Weibull distribution, provides an average and a median appliance lifetime. DOE calculated the average lifetime for both product classes at 15.4 years.

The Weibull distribution is a probability distribution commonly used to measure failure rates.[a] Its form is similar to an exponential distribution, which models a fixed failure rate, except that a Weibull distribution allows for a failure rate that changes over time in a particular fashion. The cumulative Weibull distribution takes the form:

$$P(x) = e^{-\left(\frac{x-\theta}{\alpha}\right)^{\beta}} \text{ for } x > \theta \text{ and}$$

$$P(x) = 1 \text{ for } x \leq \theta$$

Where:

$P(x)$ = probability that the appliance is still in use at age x,
x = appliance age,
α = scale parameter, which would be the decay length in an exponential distribution,
β = shape parameter, which determines the way in which the failure rate changes through time, and
θ = delay parameter, which allows for a delay before any failures occur.

When $\beta = 1$, the failure rate is constant over time, giving the distribution the form of a cumulative exponential distribution. In the case of appliances, β commonly is greater than 1, reflecting an increasing failure rate as appliances age. Figure 8.2.3 shows the Weibull retirement function for dishwashers.

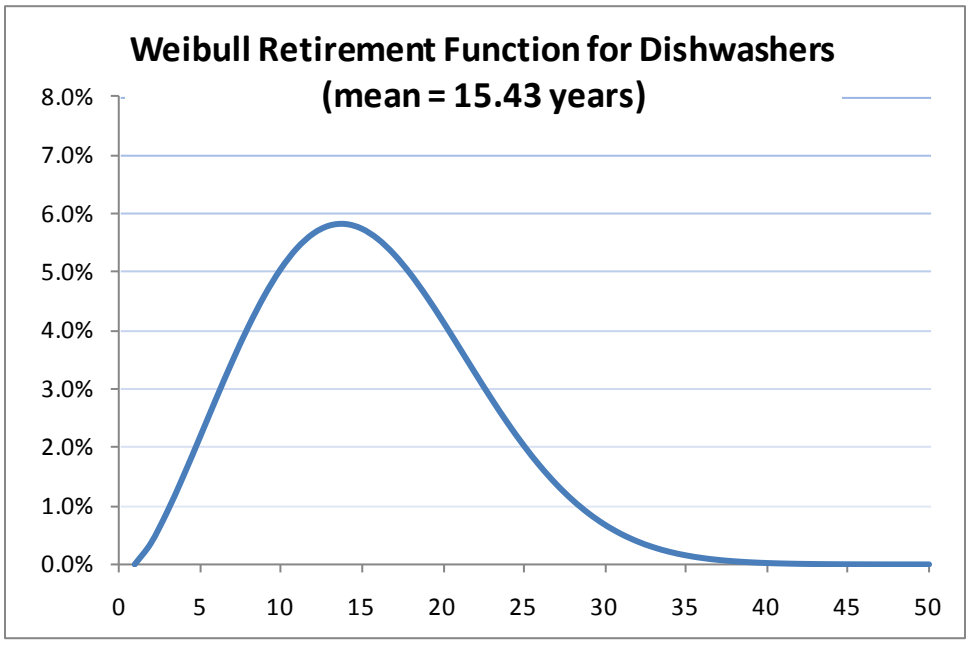

Figure 8.2.3 Weibull Retirement Function for Dishwashers

[a] For reference on the Weibull distribution, see sections 1.3.6.6.8 and 8.4.1.3 of the *NIST/SEMATECH e-Handbook of Statistical Methods*, <www.itl.nist.gov/div898/handbook/>.

Appendix 8D presents the Weibull distributions that DOE used in the LCC and PBP analysis.

8.2.4 Discount Rates

The discount rate is the rate at which DOE discounted future consumer expenditures to establish their present value. DOE derived the discount rates for the LCC and PBP analyses from estimates of the finance cost of purchasing the considered products. Following financial theory, the finance cost of raising funds to purchase appliances can be interpreted as: (1) the financial cost of any debt incurred to purchase products, or (2) the opportunity cost of any equity used to purchase products. DOE considers both of these interpretations.

In the case of individual households, the financing of purchasing products installed in new homes is different from the financing of appliances bought directly by consumers (i.e., as a replacement for a failed unit or as a new purchase for an existing household that does not already own the appliance). Thus, DOE used different discount rates for these residential purchases.

8.2.4.1 Residential Discount Rates for Products Purchased in Existing Households

Households use a variety of methods to finance the purchase of major appliances. In principle, one could estimate the interest rates on the actual financing methods used to purchase appliances. However, the shares of different financing methods in total appliance purchases are unknown.

DOE's approach involves identifying all possible debt or asset classes that might be used to purchase the considered appliances, including household assets that might be affected indirectly.[b] DOE excluded debt from primary mortgages or assets considered non-liquid (such as retirement accounts), because those financing methods are unlikely to be used by households in existing housing to purchase appliances. DOE estimated the average percentage shares of the various debt and equity classes in the average U.S. household equity and debt portfolios using data from the Federal Reserve Board's Survey of Consumer Finances (SCF) for 1989, 1992, 1995, 1998, 2001, 2004, and 2007.[11] Table 8.2.14 shows the average percentages of each considered type of debt or equity. DOE derived the mean percentage shares of each source of financing for each of the seven surveys as a basis for estimating the weight of the classes in the direct or indirect financing of the considered appliances.

[b] An indirect effect would arise if a household sold some assets in order to pay off a loan or credit card debt that might have been used to finance the appliance purchase.

Table 8.2.14 Average Shares of Considered Household Debt and Equity Types: %

Type	1989 SCF	1992 SCF	1995 SCF	1998 SCF	2001 SCF	2004 SCF	2007 SCF	Mean
Home equity loans	4.3	4.5	2.7	2.8	2.8	4.4	4.6	3.7
Credit cards	1.6	2.1	2.6	2.2	1.7	2.0	2.4	2.1
Other installment loans	2.8	1.7	1.4	1.7	1.1	1.3	1.1	1.6
Other residential loans	4.4	6.9	5.2	4.3	3.1	5.8	7.1	5.3
Other lines of credit	1.1	0.6	0.4	0.2	0.3	0.5	0.3	0.5
Checking accounts	5.8	4.7	4.9	3.9	3.6	4.2	3.4	4.4
Savings & money market	19.2	18.8	14.0	12.8	14.2	15.1	13.0	15.3
Certificates of deposit	14.5	11.7	9.4	7.0	5.4	5.9	6.5	8.6
Savings bonds	2.2	1.7	2.2	1.1	1.2	0.9	0.7	1.4
Bonds	13.8	12.3	10.5	7.0	7.9	8.4	6.7	9.5
Stocks	22.4	24.0	25.9	36.9	37.5	28.0	28.6	29.0
Mutual funds	8.0	11.1	20.9	20.1	21.3	23.4	25.5	18.6
Total	100	100	100	100	100	100	100	100

DOE estimated interest or return rates associated with each type of equity and debt. The source for the interest rates for loans, credit cards, and lines of credit was the Federal Reserve Board's SCF in 1989, 1992, 1995, 1998, 2001, 2004, and 2007. Table 8.2.15 shows the average nominal rates in each year, and the inflation rates used to calculate real rates. DOE calculated effective interest rates for home equity loans in a similar manner as for mortgage rates, because interest on both such loans is tax deductible. Table 8.2.16 shows the average effective real rates in each year and the mean rate across the years. Because the interest rates for each type of household debt reflect economic conditions throughout numerous years, they are expected to be representative of rates in the year in which amended standards would take effect.

Table 8.2.15 Average Nominal Interest Rates for Household Debt

Type of Debt	Average Nominal Interest Rate %							
	1989	1992	1995	1998	2001	2004	2007	Mean
Home equity loans	11.5	9.6	9.6	9.8	8.7	5.7	7.9	9.0
Credit cards*	-	-	14.2	14.5	14.2	11.7	12.6	13.4
Other installment loans	9.0	7.8	9.3	7.8	8.7	7.4	10.4	8.6
Other residential loans	8.8	7.6	7.7	7.7	7.5	6.0	6.3	7.4
Other line of credit	14.8	12.7	12.4	11.9	14.9	8.8	12.7	12.6
Inflation rate	4.82	3.01	2.83	1.56	2.85	2.66	2.85	

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1989, 1992, 1995, 1998, 2001, 2004, and 2007.
* No interest rate data available for credit cards in 1989 or 1992.

Table 8.2.16 Average Real Effective Interest Rates for Household Debt

Type of Debt	Average Real Interest Rate %							
	1989	1992	1995	1998	2001	2004	2007	Mean
Home equity loans	3.8	4.3	4.4	5.8	3.8	1.9	3.3	3.9
Credit cards*	-	-	11.0	12.7	11.1	9.1	9.7	10.7
Other installment loans	4.9	5.8	7.0	6.6	6.1	5.4	5.8	6.0
Other residential loans	4.0	4.7	4.8	6.0	4.6	3.3	3.4	4.4
Other lines of credit	9.6	9.4	9.3	10.2	7.3	6.0	9.7	8.8

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1989, 1992, 1995, 1998, 2001, 2004, and 2007.
* No interest rate data available for credit cards in 1989 or 1992.

DOE developed a probability distribution of interest rates for each debt class based on the *SCF* data. To account for variation among households, DOE sampled a rate for each household from the distributions for the appropriate debt class. Appendix 8E presents the probability distribution of interest rates for each debt class that DOE used in the LCC and PBP analyses.

No similar rate data are available from the *SCF* for the asset classes, so the Department derived data for these classes from national historical data. The interest rates associated with certificates of deposit (CDs),[12] savings bonds,[13] and bonds (AAA corporate bonds)[14] are from Federal Reserve Board time-series data covering 1977–2010. DOE assumed rates on checking accounts to be zero. Rates on savings and money market accounts are from Cost of Savings Index data covering 1984–2010.[15] The rates for stocks are the annual returns on the Standard and Poor's (S&P) 500 in 1977–2010.[16] Rates for mutual fund are a weighted average of the stock

rates (two-thirds weight) and the bond rates (one-third weight) in each year from 1977–2010. DOE adjusted the nominal rates to real rates using the annual inflation rate for each year. Average nominal and real interest rates for the classes of assets are listed in Table 8.2.17. Because the interest and return rates for each type of asset reflect economic conditions throughout numerous years, they are expected to be representative of rates in the year in which amended standards would take effect.

Table 8.2.17 Average Nominal and Real Interest Rates for Household Equity

Type of Equity	Average Nominal Rate %	Average Real Rate %
Checking accounts	-	0.0
Savings and money market	5.2	2.2
CDs	6.3	2.1
Savings bonds	7.5	3.3
Bonds	8.3	4.1
Stocks	12.1	7.8
Mutual funds	10.6	6.3

Table 8.2.18 summarizes the mean real effective rates of each type of equity or debt as well as the average percentage of the debt and asset for all U.S. households over the 7 years of survey data. DOE determined the average percentage of each type of debt and asset using SCF data for 1989, 1992, 1995, 1998, 2001, 2004, and 2007. Each year of SCF data provides the amount of debts and assets held by each U.S. household. DOE averaged the percentages for the 7 years of survey data to arrive at the percentages shown in Table 8.2.18. The average rate across all types of household debt and equity, weighted by the shares of each class, is 5.1 percent.

Table 8.2.18 Shares and Interest or Return Rates Used for Household Debt and Equity

	Average Share of Household Debt plus Equity %*	Mean Effective Real Rate %**
Home equity loans	3.7	3.9
Credit cards	2.1	10.7
Other installment loans	1.6	6.0
Other residential loans	5.3	4.4
Other line of credit	0.5	8.8
Checking accounts	4.4	0.0
Savings and money market accounts	15.3	2.2
Certificates of deposits	8.6	2.1
Savings bonds	1.4	3.3
Bonds	9.5	4.1
Stocks	29.0	7.8
Mutual funds	18.6	6.3
Total/weighted-average discount rate	100	**5.1**

* Not including primary mortgage or retirement accounts.

** Adjusted for inflation and, for home equity loans, loan interest tax deduction.

DOE developed a normal probability distribution of interest rates for each asset type by using the mean value and standard deviation from the distribution. To account for variation among households, DOE sampled a rate for each household from the distributions for the appropriate asset class. Appendix 8E presents the probability distribution of interest rates for each asset type that DOE used in the LCC and PBP analyses.

8.2.4.2 Residential Discount Rates for Products Installed in New Housing

Appliances installed in new homes ("new-housing appliances") are purchased as part of the home, which is almost always financed with a mortgage loan. DOE estimated discount rates for new-housing appliances using the effective real (after-inflation) mortgage rate for homebuyers. This rate corresponds to the interest rate after deduction of mortgage interest for income tax purposes and after adjusting for inflation (using the Fisher formula).[c] For example, a 6-percent nominal mortgage rate has an effective nominal rate of 4.5 percent for a household at the 25-percent marginal tax rate. When adjusted for an inflation rate of 2 percent, the effective real rate becomes 2.45 percent.

The data sources DOE used for mortgage interest rates were the SCF in 1989, 1992, 1995, 1998, 2001, 2004, and 2007. Using the appropriate SCF data for each year, DOE adjusted

[c] Fisher formula is given by: Real Interest Rate = [(1 + Nominal Interest Rate) / (1 + Inflation Rate)] – 1.

the mortgage interest rate for each relevant household in the SCF for mortgage tax deduction and inflation (see Table 8.2.19). In cases where the effective interest rate is equal to or below the inflation rate (resulting in a negative real interest rate), DOE set the real effective interest rate to zero.

The average nominal mortgage rate carried by homeowners in these 6 years was 7.9 percent. Since the mortgage rates carried by households in these years were established over a range of time, DOE believes they are representative of rates that may apply when amended standards take effect. After adjusting for inflation and interest tax deduction, effective real interest rates on mortgages across the six surveys averaged 3.0 percent.

Table 8.2.19 Data Used to Calculate Real Effective Mortgage Rates

Year	Mortgage Interest Rates in Selected Years %			
	Average Nominal Interest Rate	Inflation Rate[17]	Marginal Tax Rate Applicable to Mortgage Interest[18]	Average Real Effective Interest Rate
1989	9.7	4.82	24.3	2.4
1992	9.1	3.01	23.4	3.8
1995	8.2	2.83	24.1	3.3
1998	7.9	1.56	23.9	4.4
2001	7.6	2.85	22.9	2.9
2004	6.2	2.66	20.6	2.2
2007	6.3	2.85	21.6	2.1
Average	7.9			**3.0**

To account for variation among households, DOE sampled a rate for each household in the RECS samples from a distribution of mortgage rates. DOE developed the distribution based on the SCF data. Appendix 8E presents the probability distribution that DOE used in the LCC and PBP analyses.

8.2.5 Compliance Date

In the context of EPCA, the compliance date is the future date when parties subject to the requirements of a new or amended standard must comply. EPCA requires DOE, no later than January 1, 2015, to determine whether amended standards for dishwashers are warranted. The compliance date for any amended standards would be January 1, 2018. (42 U.S.C. 6295(g)(10)(B)) Where appropriate, DOE calculated the LCC and PBP for dishwashers as if consumers would purchase new products in 2018. Trial Standard Level (TSL) 2, which corresponds to the Consensus Agreement level for standard dishwashers, has a compliance date of Jan. 1, 2013. Thus, for TSL 2, DOE used 2013 as the compliance year. Further discussion of the TSLs is provided in chapter 10, section 10.1.1.

DOE calculated the LCC for all consumers as if they each would purchase a new product in the year of compliance with an amended standard takes effect.

8.2.6 Product Assignment for the Base Case

To accurately estimate the percentage of consumers that would be affected by a particular standard level, DOE took into account the distribution of product efficiencies expected for the compliance year. In other words, rather than analyzing the impacts of a particular standard level assuming that all consumers are currently purchasing products at the baseline level, DOE conducted the analysis by taking into account the full breadth of product efficiencies that consumers purchase under the base case (i.e., the case without new energy efficiency standards).

As noted in section 8.1.1, DOE's approach for conducting the LCC analysis for residential dishwashers relied on developing samples of households that use each product class. DOE used a Monte Carlo simulation technique to perform the LCC calculations for the households in the sample. Using the base-case distribution of product efficiencies, DOE assigned each household in the sample a unique product efficiency. Because it performed the LCC calculations on a household-by-household basis, DOE based the LCC for a particular candidate standard level (CSL) on the efficiency of the product assigned to each given household. For example, if a household was assigned a product efficiency that is greater than or equal to the efficiency of the CSL under consideration, the LCC calculation would reveal that this household is not impacted by an increase in product efficiency that is equal to the standard level. The distributions of product efficiencies that DOE used for the LCC analysis for dishwashers are discussed below.

AHAM provided the distribution of standard-sized and compact dishwashers efficiencies sold in 2010.[19] Based on these shipment-weighted efficiency data, the base-case distributions for standard-sized and compact dishwashers were calculated. DOE used an exponential function, displayed in Figure 8.4.2, to model the historical decline in shipment-weighted annual average energy use shown in the AHAM data and forecast that decline into the future.

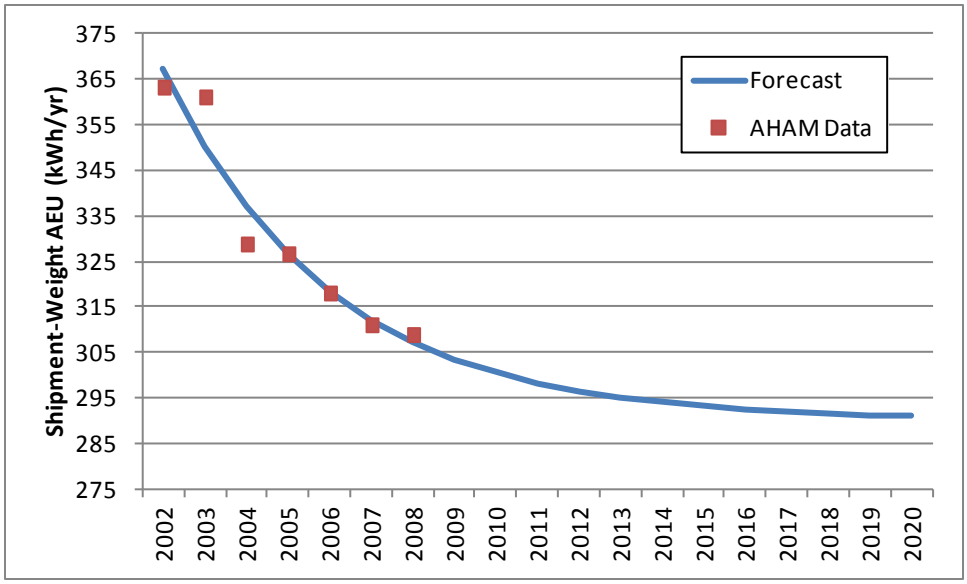

Figure 8.2.4 Historic and Projected Base Case Trend in Dishwasher Average Energy Use

DOE then combined this predicted trend with the market share trends for various efficiency levels to predict the market shares for each efficiency level in 2013 and 2018. To predict the market shares by efficiency level in 2013 and 2018, DOE observed the market trends present in the AHAM data and assumed those trends would continue in a manner consistent with the decline in total average energy use shown above. The historical and forecast market shares are shown in Table 8.2.20 and Table 8.2.21, along with shipment-weighted annual energy use (SWAEU).

Table 8.2.20 Standard Dishwashers: Efficiency Market Share Data and Base-Case Forecast: %

Efficiency Level	2008	2009	2010	2013	2018
Baseline	56.4	38.7	3.8	3.8	3.8
1	30.0	41.1	51.8	32.3	25.2
2	7.8	8.9	21.5	28.0	32.7
3	5.8	5.2	15.3	16.4	18.5
4	0.0	4.0	5.0	13.8	10.8
5	0.0	2.0	2.5	5.6	9.0
SWAEU	338.4	326.5	309.0	295.1	291.6

Table 8.2.21 Standard-Sized Dishwashers: Base-Case Efficiency Market Shares for 2018

Efficiency Level	Annual Energy Use kWh/year	Water Use gal/cycle	Market Share %
Baseline	355	6.50	3.8
1	324	5.80	25.2
2	307	5.00	32.7
3	295	4.25	18.5
4	234	3.80	10.8
5	180	1.60	9.0

For compact dishwashers, AHAM data for efficiency distributions were not available. Thus, DOE first considered 2010 market data from the NPD Group, Inc. Those data show that nearly all shipments for both standard and compact dishwashers are at the baseline efficiency level. For the compact class base-case distribution, however, there were only two types of compact dishwashers in the NPD data set: "countertop" and "portable." DOE is not aware of any portable dishwashers currently on the market in the United States that would be classified as compact size based on the number of place settings. Further, there are no compact dishdrawer platforms included in the NPD dataset, which DOE believes represent a sizeable fraction of compact dishwasher shipments. As a result, DOE estimated compact base-case efficiencies from its research on the number of models available at each efficiency level. Of the eight compact dishwashers listed in the FTC database for manufacturer certifications in 2010, four are dishdrawer models with similar performance. Therefore, DOE allocated half of shipments to the dishdrawer platform that meets CSL 2. DOE further estimated, based on the number of countertop models and underlying platforms contained within the CEC and FTC databases, that half of remaining shipments (25 percent of total compact dishwasher shipments) would meet CSL 1, while the remaining 25 percent of compact shipments are at the baseline. Table 8.2.22 presents the market shares of the efficiency levels in the base case in 2018 for compact dishwashers.

Table 8.2.22 Compact Dishwashers: Base Case Efficiency Market Shares for 2018

Efficiency Level	Annual Energy Use kWh/year	Water Use gal/cycle	Market Share %
Baseline	260	4.50	25.0
1	222	3.50	25.0
2	154	2.10	50.0

8.3 INPUTS TO PAYBACK PERIOD ANALYSIS

The payback period (PBP) is the amount of time it takes the consumer to recover, through lower operating costs, the assumed higher purchase price of a more energy efficient product. Numerically, the PBP is the ratio of the increase in purchase price (i.e., from a less efficient design) to the decrease in annual operating costs. This type of calculation is known as a "simple"

payback period because it ignores changes in operating expense over time or the time value of money. That is, the calculation is done at an effective discount rate of zero percent.

The equation for PBP is:

$$PBP = \frac{\Delta IC}{\Delta OC}$$

Where:

ΔIC = difference in the total installed cost between the standard level unit and the baseline unit, and
ΔOC = difference in annual operating expenses.

Payback periods are expressed in years. A payback period greater than the life of the product means that the increased total installed cost is not recovered in reduced operating costs.

The data inputs to PBP are the total installed cost of the product to the consumer for each efficiency level and the annual (first year) operating expenditures for each standard level. The inputs to the total installed cost are the product price and the installation cost. The inputs to the operating costs are the annual costs of energy and water, repair, and maintenance. The PBP uses the same inputs as the LCC analysis, as described in section 8.2, except that PBP does not require energy and water price trends or discount rates. Considering the PBP is a "simple" payback, the required energy and water prices are only for the year in which a new standard will take effect—in this case, 2018 (2013 for TSL 2). The energy and water prices DOE used in the PBP calculation was the price projected for that year.

8.4 RESULTS OF LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSES

This section presents the LCC and PBP results for residential dishwashers. As discussed in section 8.1.1, DOE's approach to conducting the LCC analysis relied on developing samples of households that use each product class. DOE also used probability distributions to characterize the uncertainty of many of the inputs. DOE applied a Monte Carlo simulation to calculate the LCC for the households in the sample. For each set of sample households using each product class, DOE calculated the average LCC and LCC savings and the median and average PBP for each of the standard levels.

DOE calculated LCC savings and PBPs relative to the base-case product it assigned to the households. As discussed in section 8.2.6, DOE assigned some households a base-case product that is more efficient than some of the standard levels. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific standard level and the LCC of the baseline product.

LCC and PBP calculations were performed 10,000 times on the sample of households established for each product class. Each LCC and PBP calculation was performed on a single household, which was selected from the sample based on its weight (i.e., how representative a particular household is of other households in the distribution). Each LCC and PBP calculation also sampled from the probability distributions that DOE developed to characterize many of the inputs to the analysis.

The results from the Monte Carlo simulations on 10,000 samples provided the basis for DOE to calculate the share of households with a net LCC benefit, with a net LCC cost, and with no impact for the base case and each successive efficiency level. DOE considered a household to receive no impact at a given efficiency level if DOE assigned it a base-case product having an efficiency equal to or greater than the efficiency level in question. The following sections illustrate the distributions of LCC impacts and PBPs for each product class at base-case efficiency and each efficiency level analyzed.

8.4.1 Distributions of Life-Cycle Cost for Baseline Units

The figures below are presented as frequency charts that show the distribution of LCCs, LCC impacts, and PBPs with their corresponding probability of occurrence. DOE generated the figures for the distributions from a Monte Carlo simulation run based on 10,000 samples.

Figure 8.4.1 and Figure 8.4.2 show the frequency charts for the baseline LCC for standard-sized and compact dishwashers, respectively.

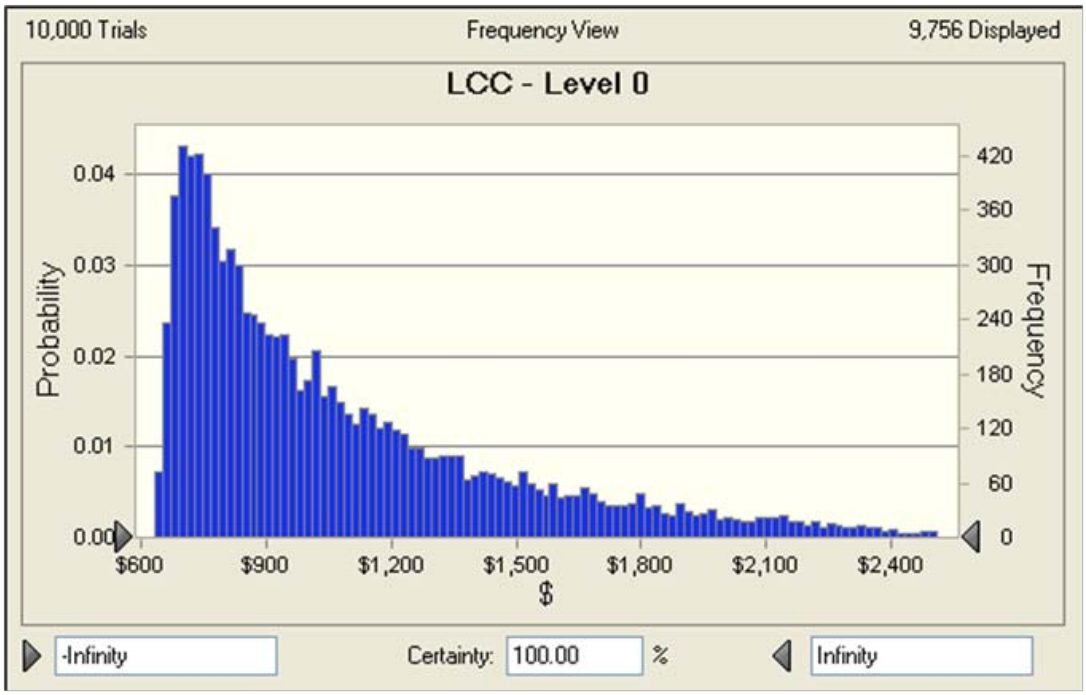

Figure 8.4.1 Standard-Sized Dishwashers: Base-Case LCC Distribution

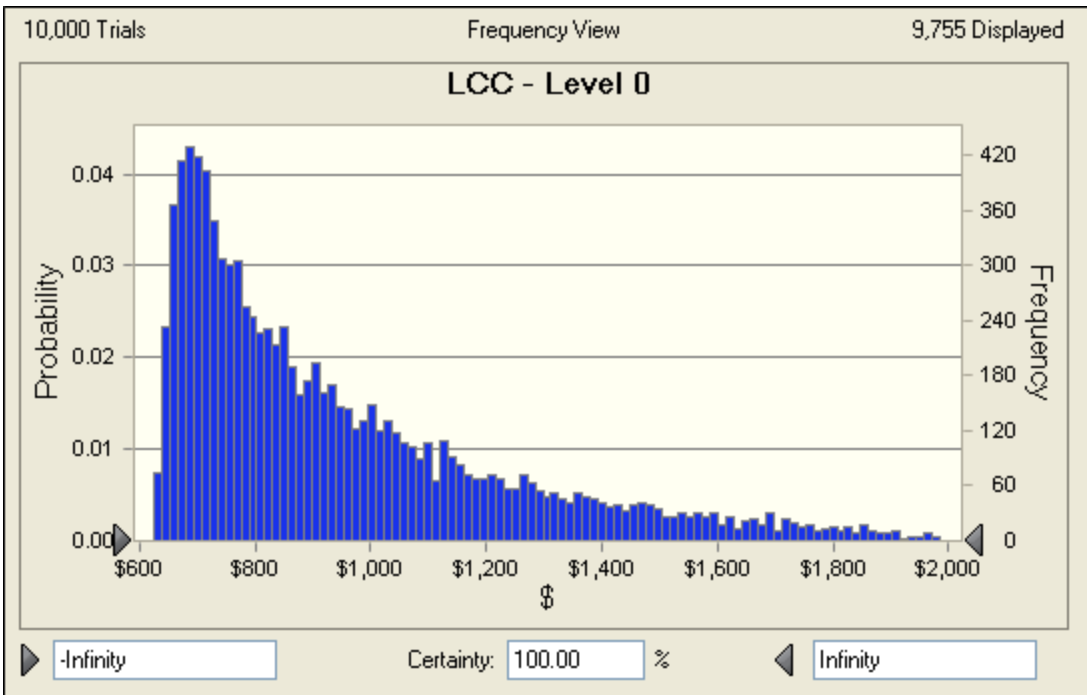

Figure 8.4.2 Compact Dishwashers: Base-Case LCC Distribution

8.4.2 Distributions of Life-Cycle Cost Under New Standard Levels

Figure 8.4.3 and Figure 8.4.4 are examples of frequency charts showing the distribution of LCC differences for standard-sized and compact dishwashers at the efficiency levels corresponding to TSL2. Refer back to section 8.2.6 on the distribution of product efficiencies under the base case. DOE can generate a frequency chart like the one shown in Figure 8.4.3 for every standard level.

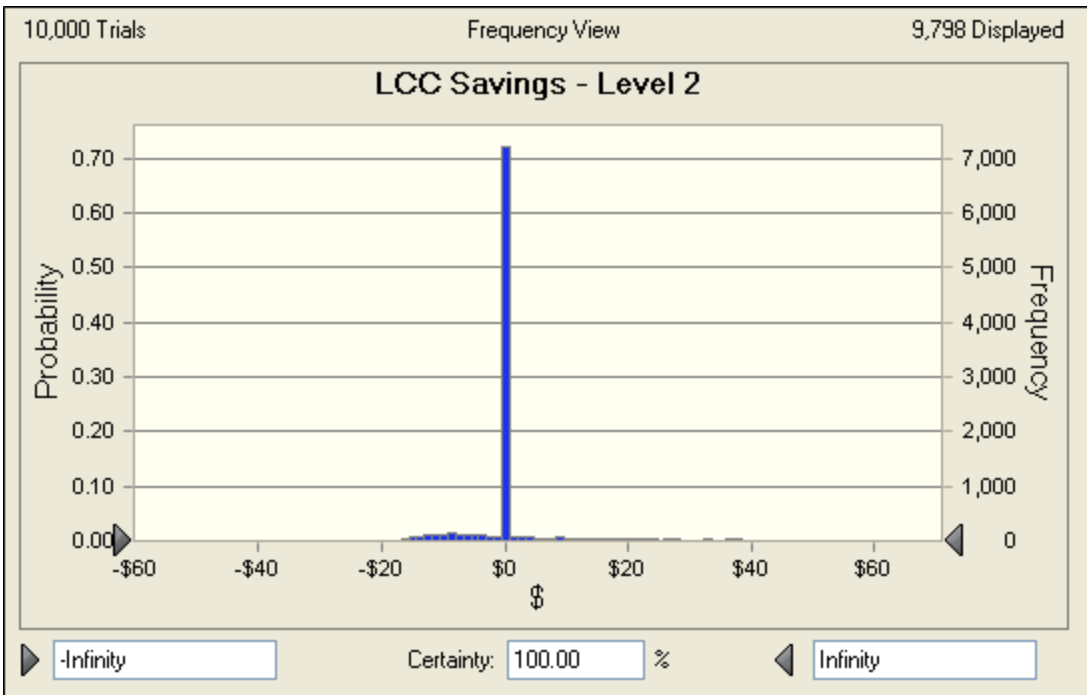

Figure 8.4.3 Standard-Sized Dishwashers: Distribution of LCC Impacts for Efficiency Level 2

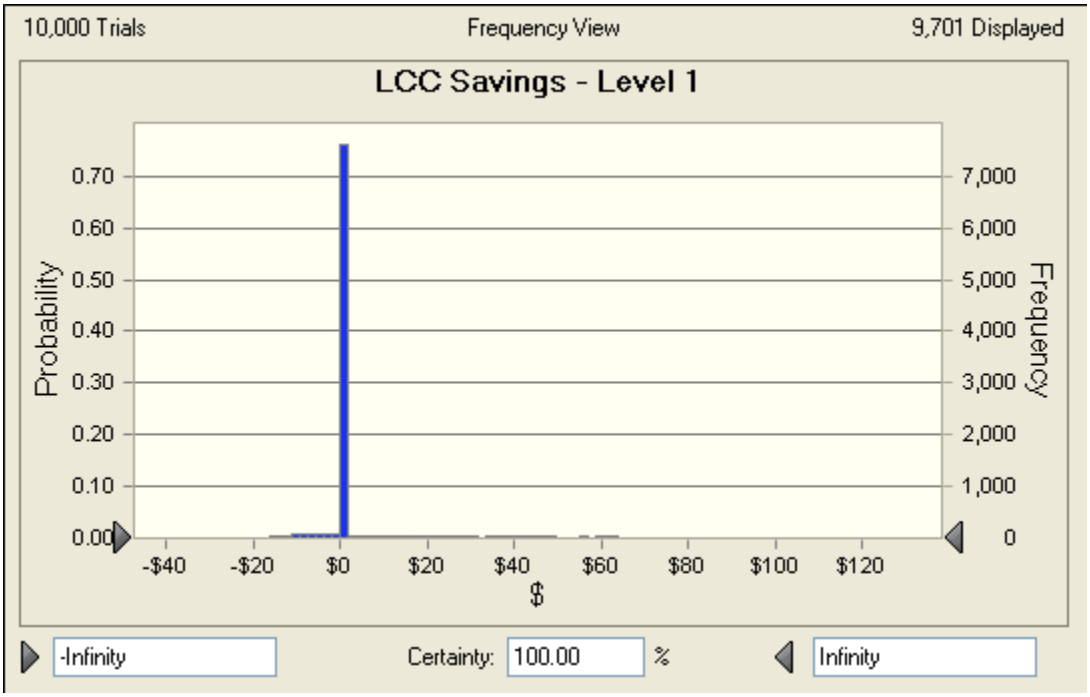

Figure 8.4.4 Compact Dishwashers: Distribution of LCC Impacts for Efficiency Level 1

8.4.3 Distribution of Payback Period Under New Standard Level

Figure 8.4.5 and Figure 8.4.6 are examples of frequency charts showing the distribution of payback periods for dishwashers at the efficiency levels corresponding to standard level 2. DOE can generate a frequency chart like the one shown in Figure 8.4.5 for every standard level.

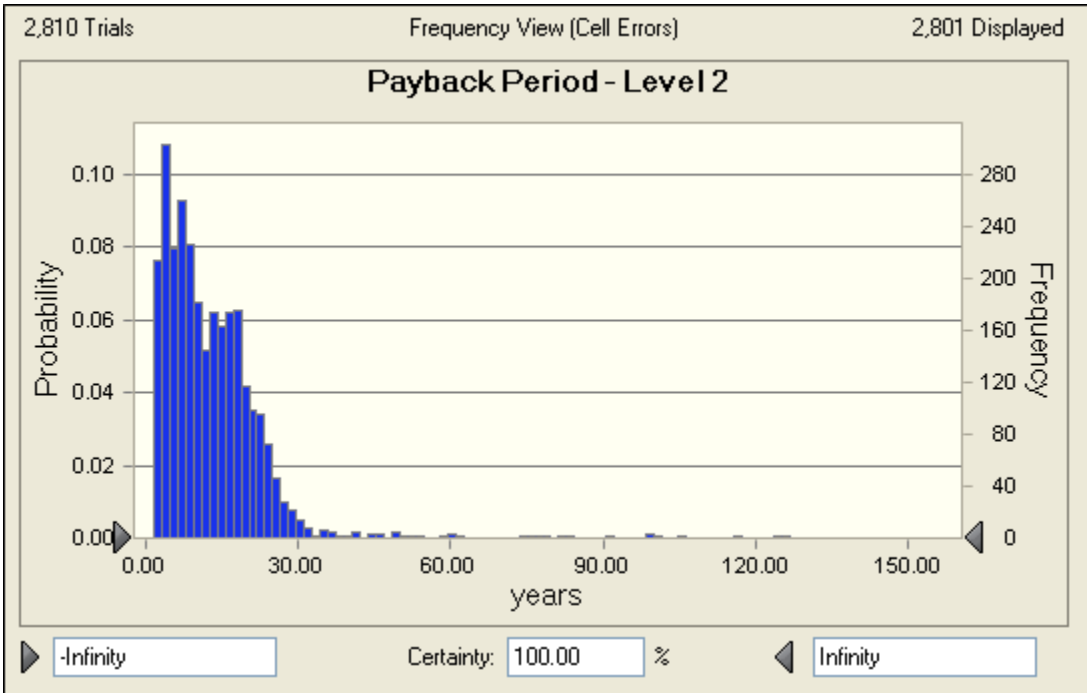

Figure 8.4.5 Standard-Sized Dishwashers: Distribution of PBPs for Efficiency Level 2

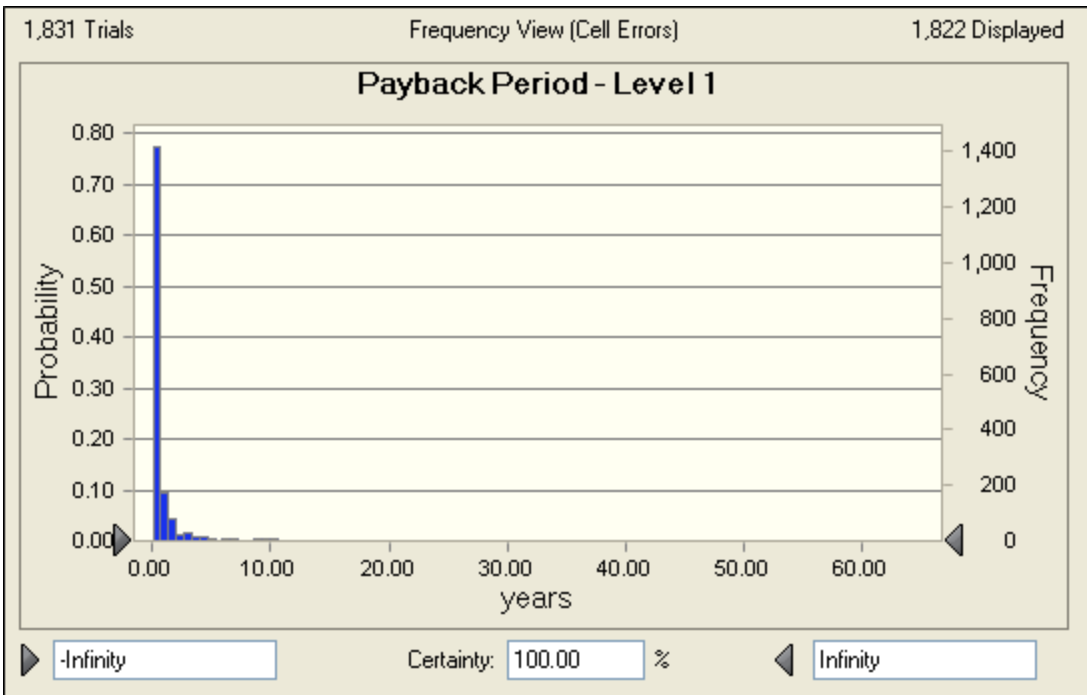

Figure 8.4.6 Compact Dishwashers: Distribution of PBPs for Efficiency Level 1

8.4.4 Life-Cycle Cost and Payback Period Summary Results

Table 8.4.1 and Table 8.4.2 show the LCC and PBP results for standard-sized dishwashers and compact dishwashers, respectively. The average operating cost is the discounted sum.

Table 8.4.1 Standard-Sized Dishwashers: Life-Cycle Cost and Payback Period Results

Level	Annual Energy Use kWh	Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period years
		Average Installed Price $	Average Operating Cost $	Average LCC $	Average Savings	% Households with Net Cost	% Households with No Impact	% Households with Net Benefit	Median
Baseline	355	630	489	1,120	NA	0	100	0	NA
1	324	656	445	1,101	$1	2	96	2	5.9
2	307	674	417	1,092	$4	14	71	15	10.9
3	295	726	396	1,122	-$15	51	38	10	33.7
4	234	734	318	1,052	$41	30	20	50	6.6
5	180	745	232	977	$108	23	9	68	4.5

Table 8.4.2 Compact Dishwashers: Life-Cycle Cost and Payback Period Results

Level	Annual	Life-Cycle Cost	Life-Cycle Cost Savings	Payback

	Energy Use kWh	Average Installed Price $	Average Operating Cost $	Average LCC $	Average Savings	% Households with			Period years Median
						Net Cost	No Impact	Net Benefit	
Baseline	260	621	356	977	NA	0	100	0	NA
1	222	623	301	923	$13	6	76	18	0.3
2	154	638	206	844	$52	5	50	44	2.1

Figure 8.4.7 and Figure 8.4.8 show the range of LCC savings for all efficiency levels considered for standard-sized and compact dishwashers, respectively. For each efficiency level, the top and the bottom of the box indicate the 75th and 25th percentiles, respectively. The bar in the middle of the box indicates the median, which means that with that efficiency level, 50 percent of the households have LCC savings above this value. The 'whiskers' at the bottom and the top of the box indicate the 5th and 95th percentiles, respectively. The small box shows the average LCC savings for each efficiency level.

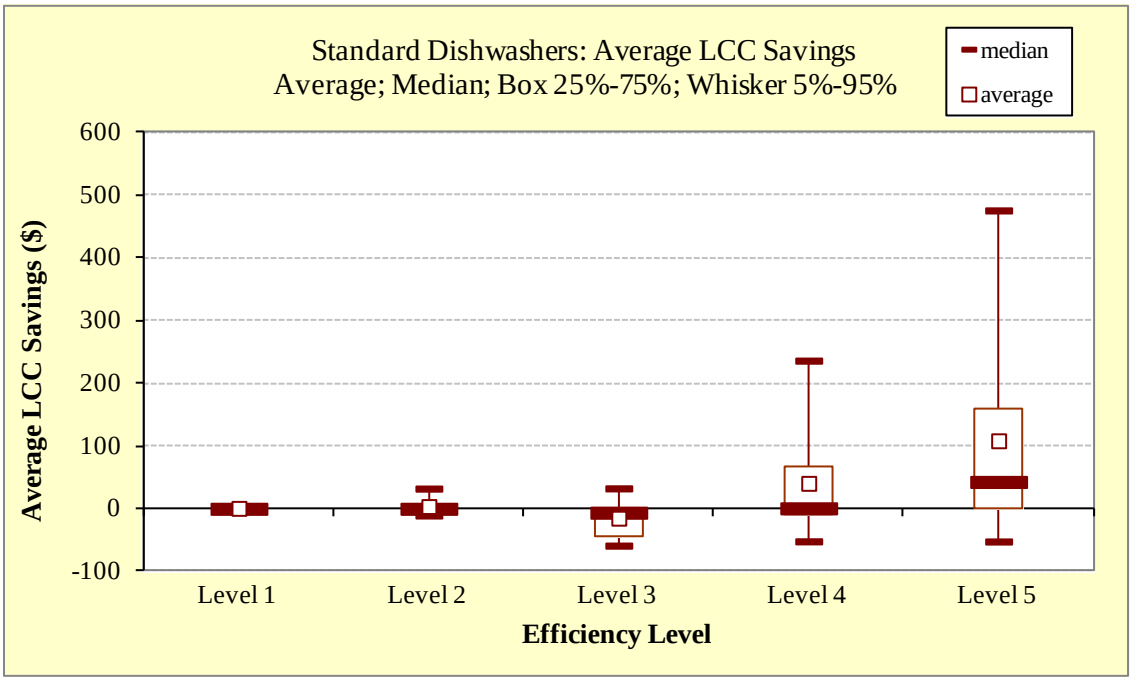

Figure 8.4.7 Range of LCC Savings for Standard-Sized Dishwashers

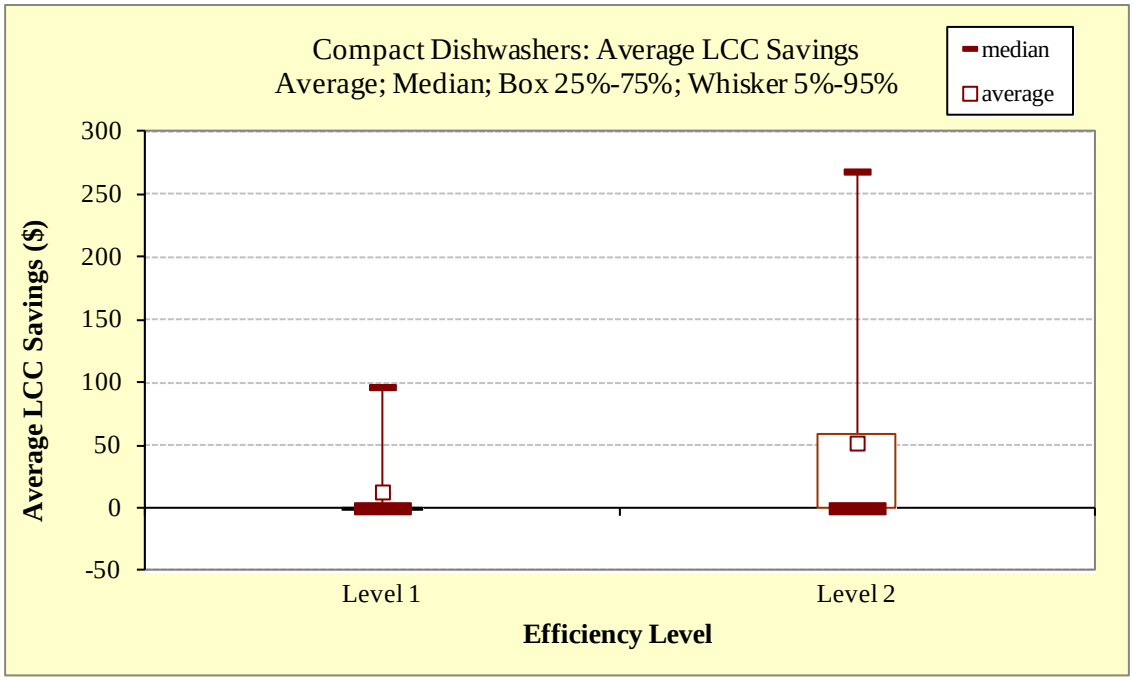

Figure 8.4.8 Range of LCC Savings for Compact Dishwashers

Figure 8.4.9 and Figure 8.4.10 show the range of PBPs for all efficiency levels for standard-sized and compact-sized dishwashers, respectively. Households that are not affected by the new standard are not included in the figures.

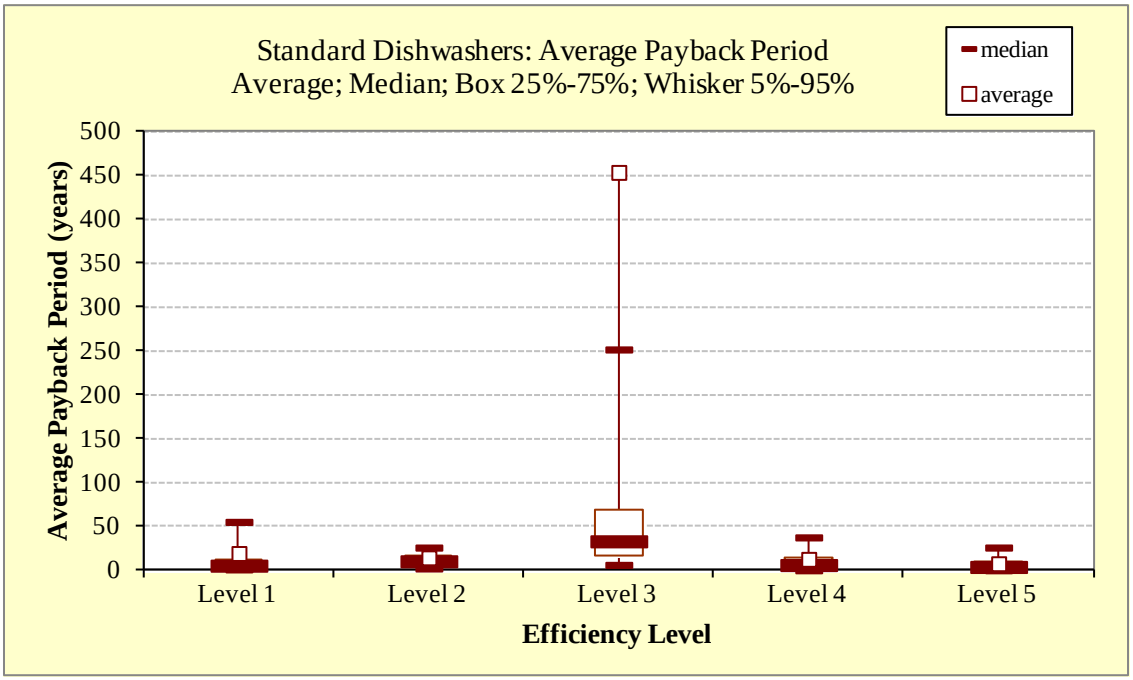

Figure 8.4.9 Range of Payback Periods for Standard-Sized Dishwashers

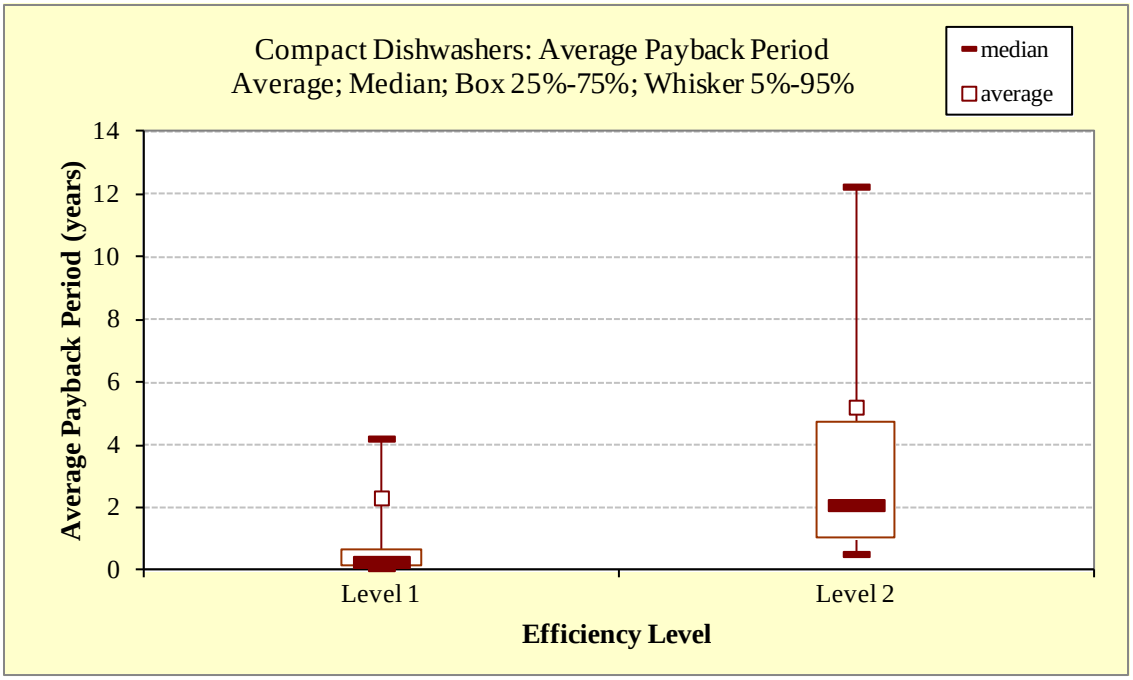

Figure 8.4.10 Range of Payback Periods for Compact Dishwashers

8.5 REBUTTABLE PAYBACK PERIOD

DOE develops rebuttable PBPs to support the legally established rebuttable presumption that an energy efficiency standard is economically justified if the additional product costs attributed to the standard are less than three times the value of the first-year energy and water cost savings. (42 U.S.C. §6295 (o)(2)(B)(iii))

The basic equation for rebuttable PBP is the same as that shown in section 8.3 on inputs to the payback period analysis. Unlike the analyses described in sections 8.2 and 8.3, however, the rebuttable PBP is not based on the use of household samples and probability distributions. Rather, the rebuttable PBP is based on discrete, single-point values. For example, DOE uses a probability distribution of regional energy prices in the distributional payback period analysis, but it uses only the national average energy and water prices from the probability distribution to determine the rebuttable PBP.

Other than the use of single-point values, the most notable difference between the distribution PBP and the rebuttable PBP is the latter's reliance on the DOE test procedure to determine a product's annual energy and water consumption. To determine the rebuttable PBP for dishwashers, DOE based the annual energy and water consumption values on the number of cycles per year specified in the DOE test procedure.[20] The number of cycles from the DOE test procedure, 215 cycles per year, is equal to the average number of cycles that DOE used in its determination of distribution PBPs.

8.5.1 Inputs

As noted in section 8.5.1, the calculation for the rebuttable PBP differs from that of the general PBP in that the inputs are discrete values rather than distributions. For the general PBP, inputs for determining total installed cost were based on single-point values. However, the variability and/or uncertainty in the inputs for determining operating costs required using distributions to calculate the general PBP. DOE used the following single-point values in determining the rebuttable PBP.

- Manufacturing costs, markups, sales taxes, and installation costs were the same as the single-point values used in the general LCC and PBP analyses.

- As described in section 8.5.1, annual energy and water consumption were based on the usage in the DOE test procedure.

- Energy and water prices were based on national average values for the year that new standards are assumed to take effect (2013 for the consensus agreement levels; 2015 for all other efficiency levels).

- Neither an average discount rate nor a lifetime is required in the rebuttable PBP calculation.

8.5.2 Results

DOE calculated rebuttable PBPs for each efficiency level relative to the distribution of product efficiencies assumed for the base case (refer back to section 8.2.6 for more details on the base-case efficiency distributions for each product). In other words, DOE did not determine the rebuttable PBP relative to the baseline efficiency level, but relative to the current distribution of product efficiencies DOE determined for the base case (i.e., the case without new standards).

Table 8.5.1 and Table 8.5.2 present the rebuttable PBPs for standard-sized and compact dishwashers, respectively.

Table 8.5.1 Standard-Sized Dishwashers: Rebuttable Payback Periods

Efficiency Level	AEU kWh/year	Water Use gal/cycle	Rebuttable PBP years
Baseline	355	6.50	-
1	324	5.80	5.26
2	307	5.00	5.40
3	295	4.25	8.85
4	234	3.80	5.57

5	180	1.60	4.00

Table 8.5.2 Compact Dishwashers: Rebuttable Payback Periods

Efficiency Level	AEU kWh/year	Water Use gal/cycle	Rebuttable PBP years
Baseline	260	4.50	-
1	222	3.50	0.23
2	154	2.10	1.02

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