CHAPTER 10: NATIONAL IMPACT ANALYSIS

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CHAPTER 10. NATIONAL IMPACT ANALYSIS

10.1 INTRODUCTION

This chapter describes the method the U.S. Department of Energy (DOE) used to estimate the national energy and water consumption impacts of trial standard levels (TSLs) for two product classes of dishwashers: standard-sized and compact. DOE evaluated the following impacts: (1) national energy and water consumption and savings (NES and NWS) attributable to each possible standard, (2) monetary value of energy savings to consumers of the considered products, (3) increased total installed cost of the products because of the standards, and (4) the net present value (NPV) of energy and water savings (i.e., the difference between the operational savings and increased total installed costs).

DOE determined both the NES and NPV for all of the TSLs considered for residential dishwashers. It performed all calculations for each of the considered products using a Microsoft Excel spreadsheet model, which is accessible on the Internet (http://www1.eere.energy.gov/buildings/appliance_standards/residential/dishwashers.html). The spreadsheets, which implement the National Impact Analysis (NIA) model, combine the calculations for determining the NES and NPV for each considered product with input from the relevant shipments model. Details and instructions for using the NIA model are provided in appendix 10A.

Chapter 9 provides a detailed description of the shipments models that DOE used to forecast future purchases of the considered products. Chapter 9 includes detailed descriptions of consumers' sensitivities to total installed cost, operating cost, and income, and how DOE captured those sensitivities within the model.

To estimate the national impacts of new standards for all the product classes considered in this rulemaking, DOE allocated the product cost and annual energy consumption of each representative product class to all product classes within its category.

10.1.1 Trial Standard Levels

DOE analyzed the benefits and burdens of four TSLs for residential dishwashers. These TSLs were developed using combinations of efficiency levels for the standard and compact product classes analyzed by DOE. Table 10.1.1 presents the TSLs and the corresponding efficiency levels for dishwashers. TSL 4 represents the maximum technologically feasible ("max-tech") improvements in energy efficiency for residential dishwashers. TSL 3 consists of the next efficiency level below the max-tech level for standard dishwashers, and the max-tech level for compacts. The efficiency levels in TSL 2 correspond to the recommended levels in the Joint Petition. TSL 1 consists of the first efficiency levels considered above the baseline.

Table 10.1.1 Trial Standard Levels for Residential Dishwashers

TSL	Standard-Sized		Compact	
	Efficiency Level	Annual Energy Use kWh	Efficiency Level	Annual Energy Use kWh
1	1	324	1	222
2	2	307	1	222
3	4	234	2	154
4	5	180	2	154

10.2 FORECASTED EFFICIENCIES FOR BASE AND STANDARDS CASES

This section describes the method DOE used to forecast the energy efficiencies of considered products under the base case and each of the potential standards cases. It provides efficiency distributions for both product classes of dishwashers.

A key factor in estimating NES and NPV is the trend in energy efficiency forecasted for the base case (without new standards) and each of the standards cases. In calculating the NES, per-unit annual energy consumption is a direct function of product efficiency. For the NPV, two inputs, the per-unit total installed cost and the per-unit annual operating cost, depend on efficiency. The first input, the per-unit total installed cost, is a direct function of efficiency. The per-unit annual operating cost, because it is a function of the per-unit annual consumption, is indirectly dependent on product efficiency.

Chapter 8 describes how DOE developed a base-case energy efficiency distribution (which yields a shipment-weighted average efficiency) for each of the considered product classes for the first year of the forecast period. To project the trend in efficiency over the entire forecast period, DOE considered recent trends and the potential effect of programs such as ENERGY STAR. As discussed in chapter 8, DOE forecasted the future decline in annual energy use using an exponential function, then used market share trends to forecast market share levels for individual efficiency levels. This projection was not performed for compact clothes washers, because too few data were available.

Table 10.2.1 provides the base-case efficiency distributions for the three years in which AHAM provided data (2008-2010, standard-sized only) as well as DOE's forecast for 2013 (the assumed effective date of new consensus standards) and 2018 (the assumed effective date of new standards in the absence of a consensus agreement).

Table 10.2.1 Dishwasher Base-Case Efficiency Distributions

Efficiency Level	Standard-Sized Base Case					Compact Base Case	
	2008 %	2009 %	2010 %	2013 %	2018 %	2013 %	2018 %
Baseline	56.4	38.7	3.8	3.8	3.8	25.0	25.0
1	30.0	41.1	51.8	32.3	25.2	25.0	25.0
2	7.8	8.9	21.5	28.0	32.7	50.0	50.0
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	197.5	197.5
SWWU	6.04	5.75	5.21	4.83	4.69	3.05	3.05

SWAEU: Shipment weighted annual energy use
SWWU: Shipment weighted water use

To determine the base-case efficiencies after 2018, DOE used the exponential function shown in Figure 10.2.1

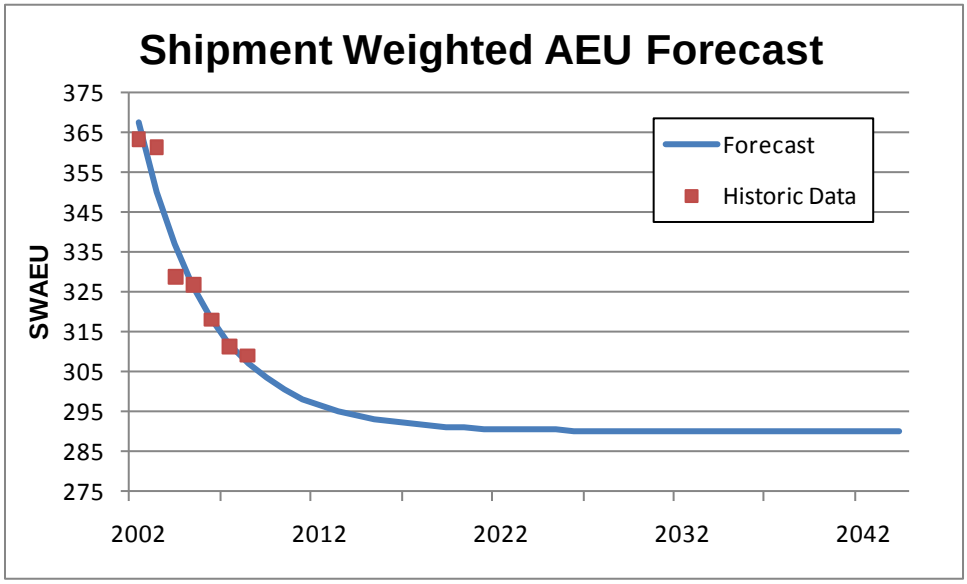

Figure 10.2.1 Standard-Sized Dishwashers: Base Case Efficiency Forecast

To determine the standards-case forecasted efficiencies, DOE assumed a "roll-up" scenario to establish the shipment-weighted efficiency for the year that standards are assumed to become effective (i.e., 2013 or 2018). DOE assumed that product efficiencies in the base case that did not meet the standard level under consideration would "roll up" to meet the new standard level. Also, DOE assumed that all product efficiencies in the base case that were above the standard level under consideration would not be affected. Table 10.2.2 and Table 10.2.3 display the roll-up scenarios used in this analysis for each TSL.

Table 10.2.2 Standard-Sized Dishwashers: Standards Case 2018 Market Shares by TSL

Efficiency Level	AEU kWh	Base Case %	TSL 1 %	TSL 2 %	TSL 3 %	TSL 4 %
Baseline	355	3.8	-	-	-	-
1	324	25.2	29.0	-	-	-
2	307	32.7	32.7	64.1	-	-
3	295	18.5	18.5	16.4	-	-
4	234	10.8	10.8	13.8	91.0	-
5	180	9.0	9.0	5.6	9.0	100.0
	SWAEU	295.1	291.6	290.4	287.8	229.2
	SWWU	4.83	4.69	4.66	4.52	3.60

SWAEU: Shipment weighted annual energy use
SWWU: Shipment weighted water use

Table 10.2.3 Compact Dishwashers: Standards Case 2018 Market Shares by TSL

Efficiency Level	AEU kWh	Base Case %	TSL 1 %	TSL 2 %	TSL 3 %	TSL 4 %
Baseline	355	25.0	-	-	-	-
1	324	25.0	50.0	50.0	-	-
2	307	50.0	50.0	50.0	100.0	100.0
	SWAEU	259.6	197.5	188.0	188.0	154.0
	SWWU	4.49	3.05	2.80	2.80	2.10

SWAEU: Shipment weighted annual energy use
SWWU: Shipment weighted water use

Using the shipment-weighted efficiency in the compliance year as a starting point, DOE maintained the same growth rate for forecasted efficiencies in the standards case as in the base case (i.e., zero growth). Thus, DOE retained a constant efficiency difference between the two cases over the length of the forecast period.

The NIA spreadsheet models for each of the products classes also incorporates user options of one percent and two percent for the growth rates of the base-case and standards-case forecasted efficiencies.

10.3 NATIONAL ENERGY AND WATER SAVINGS

DOE calculated the national energy and water savings associated with the difference between the base case and each of the potential standards cases for dishwashers. DOE calculated

cumulative energy savings throughout the forecast period, which extends from either 2013 or 2018 to 2047. The equations shown calculate energy savings; DOE used similar equations to calculate water savings.

10.3.1 Definition

The following equation shows that DOE calculated annual national energy and water savings as the difference between two projections: a base case (without new standards) and a standards case (with new standards). Positive values of NES represent energy savings (i.e., national annual energy consumption under a standard is less than under the base case).

$$\boldsymbol{NES_y = AEC_{BASE} - AEC_{STD}}$$

Cumulative energy savings are the sum of the annual national energy and water savings over the forecast period, which starts in the compliance year (2013 or 2018) and ends after 30 years (2047). The calculation is represented by the following equations:

$$NES_{cumulative} = \sum NES_y$$

$$NWS_{cumulative} = \sum NWS_y$$

DOE calculated the national annual energy and water consumption by multiplying the number or stock of each product class (by vintage) by its unit energy and water consumption (also by vintage). The calculation of the national annual energy consumption is represented by the following equation:

$$AEC = \sum STOCK_V \times UEC_V$$

DOE defined the quantities for the above expressions as follows:

AEC =	National annual energy consumption each year in quadrillion British thermal units (quads) summed over vintages of the product stock, $STOCK_V$.
NES_y =	Annual national energy savings (quads).
$STOCK_V$ =	Stock of product (millions of units) of vintage V surviving in the year for which DOE calculated annual energy consumption.
UEC_V =	Annual energy consumption per product in either kilowatt-hours (kWh) or million Btus (MMBtu) (electricity and gas consumption are converted from site energy to source energy (quads) by applying a time-dependent conversion factor).
V =	Year in which the product was purchased as a new unit.
y =	Year in the forecast.

The stock of a product depends on annual shipments and the lifetime of the product. As described in chapter 9, DOE projected product shipments under the base case and standards cases. DOE determined that the shipments projections under the standards cases would be slightly lower than under the base case, due to the higher purchase prices of the more-efficient products. In other words, DOE believes that the higher purchase prices would cause some consumers to forego purchasing new products.

To avoid including savings attributable to shipments displaced because of standards, DOE used the projected standards-case shipments and, in turn, the standards-case stock, to calculate the annual energy consumption for the base case.

10.3.2 Inputs

The inputs to the calculation of national energy savings (NES) are:

- Shipments,
- product stock ($STOCK_V$),
- annual energy consumption per unit (*UE*C),
- national annual energy consumption (*AEC*), and
- site-to-source conversion factor (*src_conv*).

10.3.2.1 Shipments

DOE forecasted shipments for each product class under the base case and all standards cases. Several factors impact forecasted shipments, including total installed costs (purchase price plus installation costs), operating cost, household income, and product lifetime. As noted earlier, the increased total installed cost of more efficient products causes some customers to forego product purchases. Consequently, shipments forecasted under the standards cases are lower than under the base case. DOE believes it would be inappropriate to count energy savings that result from reduced shipments due to standards, as described in chapter 9. Therefore, DOE did not calculate annual energy consumption for the base case using the base case shipments forecast. Instead, for each comparison of a standards case with the base case, DOE used shipments associated with that particular standards case. As a result, all of the calculated energy savings are due to higher energy efficiency in the standards case. Chapter 9, Shipments Analysis, describes, in detail, the method DOE used to calculate and generate the shipments forecasts for each product class.

10.3.2.2 Product Stock

The product stock in a given year is the number of products shipped from earlier years that survive in that given year. The NIA model tracks the number of units shipped each year. DOE assumes that products have an increasing probability of retiring as they age. The probability of survival as a function of years-since-purchase is the survival function. Chapter 9 provides additional details on the survival functions that DOE used for each product class.

10.3.2.3 Annual Energy Consumption per Unit

DOE used the shipment-weighted annual energy use (SWAEU) presented in section 10.2 for the base case and standards cases, along with the data on annual energy consumption presented in chapters 7 and 8, to estimate the shipment-weighted average annual per-unit energy consumption under the base and standards cases. The average annual per-unit energy consumption projected for 2018 (2013 for TSL 2) for each product category is shown in Table 10.3.2.1.

Table 10.3.1 Shipment-Weighted Average Per-Unit Annual Energy and Water Consumption

		Trial Standard Level			
	Baseline	**1**	**2**	**3**	**4**
Standard-Sized					
SWAEU	291.6	290.4	287.8	229.2	180.0
Avg. Elec Use kWh/yr	185.4	184.8	185.3	147.5	143.7
Avg. Gas Use MMBtu/yr	0.45	0.45	0.44	0.35	0.15
Avg. Oil Use MMBtu/yr	0.03	0.03	0.03	0.02	0.01
Water Use 1,000 gal/yr	1.01	1.00	0.97	0.77	0.34
Compact					
SWAEU	197.5	188.0	188.0	154.0	154.0
Avg. Elec Use kWh/yr	128.3	124.5	124.5	106.4	106.4
Avg. Gas Use MMBtu/yr	0.30	0.27	0.27	0.20	0.20
Avg. Oil Use MMBtu/yr	0.02	0.02	0.02	0.01	0.01
Water Use 1,000 gal/yr	0.66	0.60	0.60	0.45	0.45

As described in section 9.4 of Chapter 9, Shipments Analysis, DOE forecasted a drop in dishwasher shipments due to the increase in purchase price due to standards-related efficiency increases. DOE assumed that the consumers who forgo the purchase of a dishwasher due to the higher purchase price would then hand wash their dishes. To properly account for the energy and water use impacts of dishwasher standards, DOE included the energy and water use of hand washing dishes. Several studies have compared the energy and water use of both hand washing dishes to using a dishwasher. All the studies state that the energy and water use impacts of moving from machine washing to hand washing dishes vary widely based on consumer habits. A 2005 study conducted at Bonn University in Germany indicated that, on average, hand washing used 67 percent more energy and over 450 percent more water.[1] A 2006 United Kingdom (UK) study quantified the energy and water consumption of hand washing as a function of place settings. The study demonstrated that, on average, for eight place settings, hand washing used approximately 210 percent more energy and 250 percent more water.[2] Table 10.3.2 summarizes the average results from the Bonn and UK studies as well as the estimates that DOE used in its NIA. DOE decided to average the results from the two most recent studies to estimate that hand washing would use 140 percent more energy and 350 percent more water than dishwashing. In

the NIA model for dishwashers, DOE implemented this estimate to quantify the energy and water impacts of those consumers that forgo a dishwasher purchase.

Table 10.3.2 Energy and Water Use Impacts of Hand Washing compared to Dishwashing

Study	Percent Increase for Hand Washing Relative to Dishwashing %	
	Energy Use	Water Use
Bonn University*	67	450
UK**	210	250
DOE estimate	140	350

Sources: *Bonn University, 2005. **UK, Market Transformation Programme, 2006.

10.3.2.4 National Annual Energy Consumption

The national annual energy and water consumption (AEC, AWC) is the product of the annual energy and water consumption per unit and the number of units of each vintage (V). This approach accounts for differences in unit energy consumption from year to year. As shown in section 10.3.1, DOE used the equation below to calculate the annual energy consumption; the equations for water consumption are the same as the equations for energy consumption.

$$AEC = \sum STOCK_V \times UEC_V$$

To determine national annual energy consumption, DOE calculated the annual energy consumption at the site and then applied a conversion factor to calculate primary energy consumption, described below. Annual water consumption is calculated at the site only without the application of a conversion factor.

10.3.2.5 Energy Site-to-Source Conversion Factors

In determining national annual energy consumption, DOE initially calculated the annual energy consumption at the site (for electricity, the energy in kWh consumed at the household or establishment). It then used site energy consumption to calculate primary (source) energy consumption by applying a conversion factor to account for losses associated with the generation, transmission, and distribution of electricity. The site-to-source conversion factor is a multiplicative factor used to convert site energy consumption into primary or source energy consumption, expressed in quads (quadrillion Btus). DOE used annual site-to-source conversion

factors based on the version of the National Energy Modeling System (NEMS)[a] that corresponds to EIA's *Annual Energy Outlook 2011* (AEO 2011).[3] The factors are marginal values, which represent the response of the system to an incremental decrease in consumption. For electricity, the conversion factors change over time in response to projected changes in generation sources (*i.e.*, the types of power plants projected to provide electricity to the Nation). Table 10.3.3 shows the site-to-source conversion factors from 2010 to the end of the forecast period. DOE assumed that conversion factors remain at 2035 values throughout the rest of the forecast.

Table 10.3.3 Site-to-Source Conversion Factors for Electricity and Natural Gas

Year	Electricity Btu/kWh	Natural Gas Btu/Btu	Year	Electricity Btu/kWh	Natural Gas Btu/Btu
2010	7,009	1.07	2023	6,506	1.07
2011	6,827	1.07	2024	6,534	1.07
2012	6,651	1.07	2025	6,534	1.07
2013	6,549	1.07	2026	6,538	1.07
2014	6,486	1.07	2027	6,552	1.07
2015	6,448	1.07	2028	6,555	1.07
2016	6,443	1.07	2029	6,551	1.07
2017	6,433	1.07	2030	6,548	1.07
2018	6,427	1.07	2031	6552	1.07
2019	6,425	1.07	2032	6,551	1.07
2020	6,436	1.07	2033	6,548	1.07
2021	6,468	1.07	2034	6,550	1.07
2022	6,483	1.07	2035–2047	6,561	1.07

Source: NEMS, 2011.

10.4 NET PRESENT VALUE

DOE calculated the net present value (NPV) of the increased product cost and reduced operating cost associated with the difference between the base case and each potential standards case for the considered residential dishwasher product classes.

[a] For more information on NEMS, please refer to the U.S. Department of Energy, Energy Information Administration documentation. A useful summary is *National Energy Modeling System: An Overview 2000*, DOE/EIA-0581(2000), March 2000. EIA approves use of the name NEMS to describe only an official version of the model without any modification to code or data. Because this analysis entails some minor code modifications and the model is run under various policy scenarios that are variations on EIA assumptions, DOE refers to the model by the name NEMS-BT (BT is DOE's Building Technologies Program, under whose aegis this work has been performed). NEMS-BT was previously called NEMS-BRS.

10.4.1 Definition

The NPV is the value in the present of a time series of costs and savings. The NPV is described by the equation:

$$\boldsymbol{NPV = PVS - PVC}$$

Where:

PVS = Present value of operating cost savings, and
PVC = Present value of increased total installed costs (including purchase price and installation costs).

DOE determined the PVS and PVC according to the following expressions:

$$PVS = \sum OCS_y \times DF_y$$

$$PVC = \sum TIC_y \times DF_y$$

Where:

OCS = Total annual savings in operating costs each year summed over vintages of the product stock, $STOCK_V$,
DF = Discount factor in each year,
TIC = Total annual increases in installed cost each year summed over vintages of the product stock, $STOCK_V$,
y = Year in the forecast.

DOE calculated the total annual consumer savings in operating cost by multiplying the number or stock of a given product class (by vintage) by its per-unit operating cost savings (also by vintage). DOE calculated the total annual increases in consumer product cost by multiplying the number or shipments of the given product class (by vintage) by its per-unit increase in consumer product cost (also by vintage). The calculation of total annual operating cost savings and total annual product cost increases is represented by the following equations.

$$OCS_y = \sum STOCK_V \times UOCS_V$$

$$TIC_y = \sum SHIP_y \times UTIC_y$$

Where:

$STOCK_V$ = stock of products of vintage V that survive in the year for which DOE calculated annual energy consumption,
$UOCS_V$ = annual per-unit savings in operating cost;
V = year in which the product was purchased as a new unit;
$SHIP_y$ = shipments of products in year y; and
$UTIC_y$ = annual per-unit increase in installed product cost in year y.

DOE determined the total increased product cost for each year from the effective date of a potential standard to 2047. DOE determined the present value of operating cost savings for each year from the effective date of the standard to the year when all units purchased by 2047 have been retired. DOE calculated costs and savings as the difference between a standards case and a base case without new standards.

DOE developed a discount factor from the national discount rate and the number of years between the "present" (i.e., year to which the sum is being discounted) and the year in which the costs and savings occur. The NPV is the sum over time of the discounted net savings.

10.4.2 Inputs

The inputs to the net present value (NPV) calculation are:

- total installed cost per unit;
- annual operating cost savings per unit;
- total annual increases in product cost;
- total annual savings in operating cost;
- discount factor;
- present value of costs; and
- present value of savings.

The increase in the *total annual installed cost* is equal to the annual change in the per-unit total installed cost (difference between base case and standards case) multiplied by the shipments forecasted in the standards case. As with the calculation of the NES, DOE did not calculate total annual installed costs for all of the products using base case shipments. To avoid including savings due to displaced shipments (by consumers deciding not to buy higher-cost products), DOE used the standards-case projection of shipments and, in turn, the standards-case stock, to calculate product costs. Additionally, DOE assumed that any consumers foregoing the purchase of a new unit due to standards would shift to hand washing.

The *total annual operating cost savings* are equal to the change in the annual operating costs (difference between base case and standards case) per unit multiplied by the shipments forecasted in the standards case. As noted, DOE did not calculate operating cost savings using the base case shipments. The annual operating cost includes energy and water costs.

10.4.2.1 Total Installed Cost per Unit

The average annual product cost is directly dependent on efficiency. DOE therefore used the SWAEU values presented in section 10.2 for the base case and each standards case, along with the product costs at various efficiency levels (presented in chapter 8), to estimate the shipment-weighted average annual product cost under the base and standards cases. Table 10.4.1 shows the shipment-weighted average consumer product cost based on the SWIMEFs that correspond to the base case and each standards case in 2018 (2013 for TSL 2).

Table 10.4.1 Shipment-Weighted Average Per-Unit Total Installed Costs for Base and Standards Cases

		Trial Standard Level			
	Base Case	**1**	**2**	**3**	**4**
Standard-Sized					
SWAEU	291.6	290.4	287.8	229.2	180.0
Avg. Product Cost 2010$	$690	$691	$695	$735	$745
Compact					
SWAEU	197.5	188.0	188.0	154.0	154.0
Avg. Product Cost 2010$	$630	$631	$631	$638	$638

In the preliminary analysis, DOE assumed that the manufacturer costs and retail prices of products meeting various efficiency levels remain fixed, in real terms, after 2010 (the year for which the engineering analysis estimated costs) and throughout the period of the analysis. As discussed in chapter 8, for the direct final rule, DOE developed a dishwasher price trend based on an experience rate for miscellaneous household appliances. It used this trend to forecast the prices of dishwashers sold in each year in the forecast period. DOE applied the same values to forecast prices for each product class at each considered efficiency level.

To evaluate the effect of uncertainty regarding the price trend estimates, DOE investigated the impact of different product price forecasts on the consumer net present value for the considered TSLs for residential dishwashers. In addition to the default price trend, DOE considered two product price sensitivity cases: (1) a high price decline case based on an exponential fit using PPI data for 1991 to 2010; (2) a low price decline case based on an experience rate derived using PPI and shipments data for 1991 to 2000. The approach used to forecast the price trends and the results of these sensitivity cases are described in appendix 10B.

10.4.2.2 Annual Operating Cost Savings per Unit

The per-unit annual operating cost includes the costs for energy and water, repair, and maintenance. As described in section 8.2.2.4 of chapter 8, DOE assumed that potential standards would not increase maintenance and repair costs for all considered products. Therefore, DOE determined the per-unit annual operating cost savings based only on the energy and water cost savings due to a standard level. DOE determined the per-unit annual operating cost savings by

multiplying the per-unit annual energy and water consumption savings developed for each product class by the appropriate energy and water price.

As described in chapter 8, DOE forecasted energy prices based on EIA's *AEO2011*. DOE forecasted water prices based on trends in the national water price index as provided by the Bureau of Labor Statistics. The energy and water price trends are described in section 8.2.2.3 of chapter 8.

10.4.2.3 Total Annual Increases in Installed Cost

The total annual installed cost increase for any given standards case is the product of the total installed cost increase per unit due to the standard and the number of units of each vintage. This approach accounts for differences in total installed cost from year to year. Also shown in section 10.4.1, the equation to calculate the total annual installed cost increase for a given standards case is below.

$$TIC = \sum STOCK_V \times UTIC_V$$

10.4.2.4 Total Annual Savings in Operating Cost

The total annual savings in operating cost for any given standards case is the product of the annual operating cost savings per unit due to the standard and the number of units of each vintage. This approach accounts for differences in annual operating cost savings from year to year. Also shown in section 10.4.1, the equation to calculate the total annual operating cost savings for a given standards case is below.

$$OCS = \sum STOCK_V \times UOCS_V$$

As noted earlier, DOE accounted for the energy and water use of those consumers that were forced into hand washing due to the new standard. Therefore, the total annual operating cost savings take into account the additional energy and water costs for hand washing over machine dishwashing for consumers that were estimated to forego dishwasher purchases due to standards.

10.4.2.5 Discount Factors

DOE multiplies monetary values in future years by a discount factor to determine the present value. The discount factor (DF) is described by the equation:

$$\boldsymbol{DF} = \frac{1}{(1+\boldsymbol{r})^{(y-yp)}}$$

Where:

r = discount rate,
y = year of the monetary value, and
y_P = year in which the present value is being determined.

DOE estimated national impacts with both a three-percent and a seven-percent real discount rate, in accordance with the Office of Management and Budget (OMB)'s guidance to Federal agencies on the development of regulatory analysis (OMB Circular A-4, September 17, 2003), and section E., "Identifying and Measuring Benefits and Costs," therein. DOE defines the present year as 2010.

10.4.2.6 Present Value of Costs

The present value of increased installed costs is the annual installed cost increase in each year (i.e., the difference between a standards case and base case), discounted to the present and summed over the time period for which DOE considered the installation of products (that is, from the effective date of the standard, 2013 or 2018, through 2047).

The increase in total installed cost refers to both product cost and installation cost associated with the higher energy efficiency of p;roducts purchased in the standards case compared to the base case. For the NIA, DOE excludes sales tax from the product cost because it is essentially a transfer and therefore, it is appropriate to include when estimating national benefits. DOE calculated annual increases in installed costs as the difference in total installed cost for new products purchased each year multiplied by the shipments in the standards case.

10.4.2.7 Present Value of Savings

The present value of operating cost savings is the annual operating cost savings (the difference between the base case and a standards case) discounted to the present and summed over the period from the compliace year, 2013 or 2018, to the time when the last unit installed in 2047 is retired from service. Savings are decreases in operating costs associated with the higher energy efficiency of products purchased in the standards case compared to the base case. Total annual operating cost savings are the savings per unit multiplied by the number of units of each vintage surviving in a particular year.

10.5 RESULTS OF CALCULATIONS

The National Impact Analysis (NIA) model provides estimates of the NES and NPV attributable to a given candidate standards level. The inputs to the NIA Model werre discussed earlier in sections 10.3.2 (NES Inputs) and 10.4.2 (NPV Inputs). DOE generated the NES and NPV results using a Microsoft Excel spreadsheet, which is accessible on the Internet

((http://www1.eere.energy.gov/buildings/appliance_standards/residential/dishwashers.html). Details and instructions for using the spreadsheet are provided in appendix 10A.

10.5.1 Summary of Inputs

Table 10.5.1 summarizes the inputs to the NIA model. For each input a brief description of the data source is given.

Table 10.5.1 Inputs to Calculation of National Energy Savings and Net Present Value

Input	Data Description
Shipments	Annual shipments from shipments model. (See chapter 9.)
Effective date of standard	2013 or 2018
Base-case forecasted efficiencies	SWAEU determined in 2013 and 2018 for each of the considered products. SWEF held constant over forecast period of 2018–2047. (See section 10.2.)
Standards-case efficiencies	Roll-up scenario assumed for determining SWAEU in 2018 (2013 for TSL 2) for each standards case and for each of the considered products. SWAEU held constant over forecast period of 2018–2047. (See section 10.2.)
Annual energy consumption per unit	Annual weighted-average values are a function of SWEF. (See section 10.3.2.3.)
Total installed cost per unit	Annual weighted-average values are a function of the efficiency distribution. (See section 10.4.2.1.)
Energy and water cost per unit	Annual weighted-average values are a function of the annual energy and water consumption per unit and energy and water prices. (See chapter 8, section 8.2.2.3, for energy and water prices.)
Repair maintenance costs per unit	No changes in repair and maintenance cost assumed due to standards.
Forecast of installed cost per unit	Price forecast based on historical PPI data.
Forecast of energy and water prices	Energy Prices: EIA *AEO2011* forecasts (See section 8.2.2.3 of chapter 8.) Water Prices: Linear extrapolation of inflation-adjusted historical national water price index. (See section 8.2.2.3 of chapter 8.)
Energy site-to-source conversion	A time-series conversion factor that includes losses due to electricity generation, transmission, and distribution. Conversion, which changes yearly, is generated by DOE/EIA's NEMS* program.
Discount rate	3% and 7% real
Present year	Future expenses are discounted to 2011.

* Section 10.4 provides more detail on NEMS.

10.5.2 Results of National Energy and Water Savings Calculations

The following section provides national energy saving (NES) and national water savings (NWS) calculation results for the standards cases analyzed for the considered product classes. NES results, which are cumulative from 2013 or 2018 to 2047, are primary energy savings and site water savings. DOE based the inputs to the NIA model on weighted-average values, yielding results that are discrete point values, rather than a distribution of values as in the life-cycle cost and payback period analyses.

Results are presented for each TSL, which represent specific efficiency level combinations for standard-sized and compact dishwashers. Efficiency level combinations are necessary to account for the effect of the cross-price elasticity of demand observed between the two product classes, i.e., the interplay between price increase and market share between the two product classes.

Table 10.5.2 shows the NES and NWS results for the TSLs analyzed standard-sized and compact dishwashers. Table 10.5.3 shows the magnitude of the national energy savings (NES) and national water savings (NWS) if the savings are discounted at rates of 3 percent and 7 percent.

Table 10.5.2 Cumulative National Energy Savings and National Water Savings

TSL	Efficiency Level Combination		National Energy Savings quads	National Water Savings billion gallons
	Standard-Sized	Compact		
1	1	1	0.02	0.01
2	2	1	0.07	0.14
3	4	2	0.94	0.56
4	5	2	1.59	1.71

Table 10.5.3 Cumulative NES and NWS Results Discounted at Seven Percent and Three Percent

TSL	Efficiency Level Combination		NES quads		NWS billion gallons	
	Standard-Sized	Compact	7% Discounted	3% Discounted	7% Discounted	3% Discounted
1	1	1	0.00	0.01	0.00	0.01
2	2	1	0.02	0.04	0.04	0.08
3	4	2	0.20	0.46	0.12	0.28
4	5	2	0.34	0.78	0.37	0.84

10.5.3 Annual Costs and Savings

To illustrate the basic inputs to the NPV calculations, Figure 10.5.1 presents the non-discounted annual installed cost increases and annual operating cost savings at the national level for standard level 2 for dishwashers. The figure also shows the net savings, which is the difference between the savings and costs for each year. The annual product cost is the increase in the total installed cost for products purchased each year over the forecast period. The annual operating cost savings is the savings in operating costs for products operating in each year. The NPV is the difference between the cumulative annual discounted savings and the cumulative annual discounted costs. DOE could create figures like the one shown below for each of the product classes.

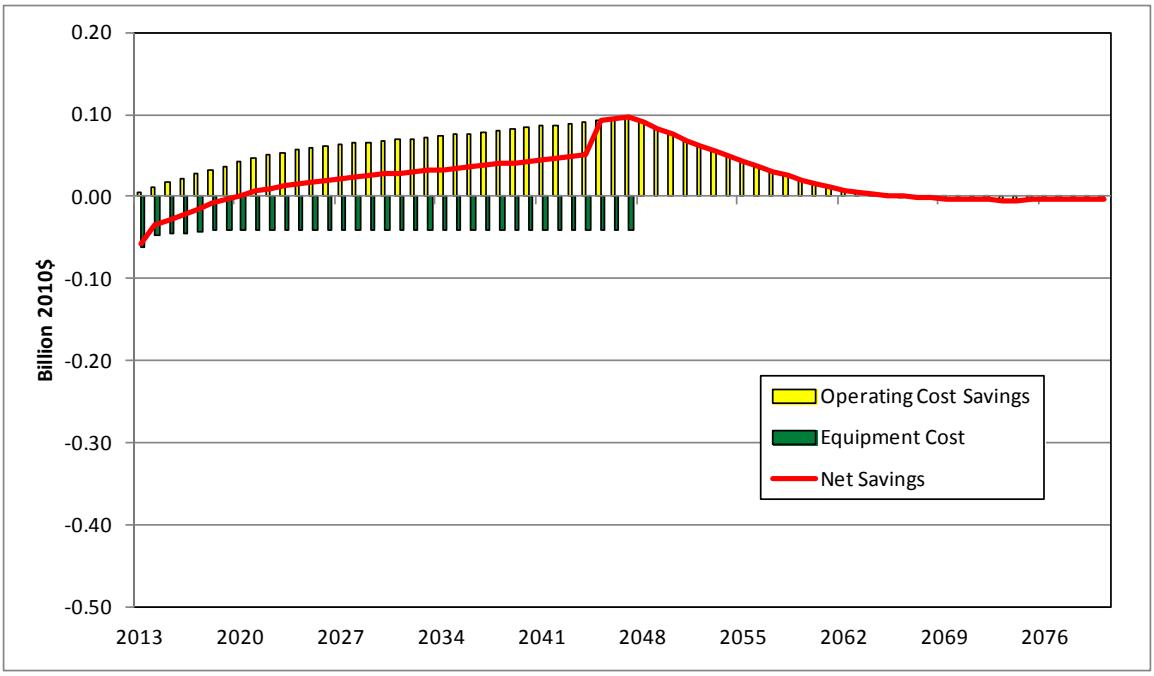

Figure 10.5.1 Non-Discounted Annual Installed Cost Increases and Annual Operating Cost Savings for Dishwashers, Standard Level 2

10.5.4 Net Present Value Results

This section provides net present value (NPV) results for the potential efficiency standards for standard-sized and compact dishwashers. Results, which are cumulative, are shown as the discounted value of savings in dollar terms. DOE based the inputs to the NIA model on weighted-average values, yielding results that are discrete point values, rather than a distribution of values as in the life-cycle cost and payback period analyses.

The present value of increased total installed costs is the total annual installed cost increase (i.e., the difference between the standards case and base case), discounted to the present

and summed over the time period in which DOE evaluated the impact of standards (i.e., from the effective date of standards, 2013 or 2018, to 2047).

Savings are decreases in operating costs associated with the higher energy efficiency of products purchased in the standards case compared to the base case. Total savings in operating costs are the savings per unit multiplied by the number of units of each vintage (i.e., the year of manufacture) surviving in a particular year. For units purchased through 2047, operating costs include energy and water consumed until the last unit is retired from service.

Table 10.5.4 presents the NPV results for the trial standard levels considered for standard-sized and compact dishwashers. As with the NES results, NPV results are presented by TSL.

Table 10.5.4 Discounted Cumulative Net Present Value of Consumer Benefit

	Efficiency Level Combination		**Net Present Value**	
TSL	Standard-Sized	Compact	7% Discount Rate billion 2010$	3% Discount Rate billion 2010$
1	1	1	0.03	0.12
2	2	1	0.08	0.46
3	4	2	1.96	6.51
4	5	2	5.88	17.45

10.6 ANNUALIZED NATIONAL COSTS AND BENEFITS

The benefits and costs of standards for residential dishwashers can be expressed in terms of annualized values over the analysis period. The annualized monetary values are the sum of (1) the annualized national economic value of the benefits from operating products that meet the proposed standards (consisting primarily of operating cost savings from using less energy, minus increases in product purchase costs, which is another way of representing consumer NPV), and (2) the monetary value of the benefits of emission reductions, including CO_2 emission reductions. The emissions reductions for each TSL are described in chapter 15, and the derivation of the monetary value of the benefits of emission reductions is described in chapter 16 of this TSD. The value of the CO_2 reductions, otherwise known as the Social Cost of Carbon (SCC), is calculated using a range of values per metric ton of CO_2 developed by a recent interagency process. The derivation of the time series of SCC values is discussed in appendix 16A of this TSD.

Although combining the values of operating savings and CO_2 reductions provides a useful perspective, two issues should be considered. First, the national operating savings are domestic U.S. consumer monetary savings that occur as a result of market transactions while the value of CO_2 reductions is based on a global value. Second, the assessments of operating cost savings and CO_2 savings are performed with different methods that use quite different time

frames for analysis. The national operating cost savings is measured for the lifetime of products shipped in the 30-year analysis period. The SCC values, on the other hand, reflect the present value of future climate-related impacts resulting from the emission of one ton of carbon dioxide in each year. These impacts go well beyond 2100.

10.6.1 Calculation Method

DOE uses a two-step calculation process to convert each time-series of costs and benefits into annualized values. First, DOE calculates a present value in the "present" year used in discounting the NPV of total consumer costs and savings.[b] For this calculation, DOE uses discount rates of three and seven percent for all costs and benefits except for the value of CO_2 reductions. For the latter, DOE uses the discount rate appropriate for each SCC time-series (see chapter 16 for discussion).

$$PV_x = \sum_{t=y_1, y_T} (x(t) \cdot (1 + r_x)^{y_{NPV} - t}) \quad [1]$$

Where:

$x(t)$ =	time-series under evaluation,
PV_x =	present value of the time-series x,
y_1 =	first year in the analysis period,
y_T =	last year in the analysis period,
y_{NPV} =	year to which the NPV of consumers' costs and savings are being discounted,
r_x =	discount rate used to discount the annual values of time-series x to year y_{NPV}.

In the second step, DOE calculates, from the present values, the fixed annual payments over a 30-year period, starting in the first year of the analysis period (i.e., the compliance year), which yields the same present values with discount rates of three and seven percent. This requires projecting the present values in the "present" year ahead to the compliance year. The fixed annual payments are the annualized values.

$$Ann_{x,r} = PV_x \cdot f_{y_1 - y_{NPV}, r} \cdot a_{30,r} = PV_x \cdot (1 + r)^{y_1 - y_{NPV}} \cdot \frac{r \cdot (1 + r)^{30}}{(1 + r)^{30} - 1} \quad [2]$$

[b] For the value of emissions reductions, DOE uses a time series that corresponds to the time period used in calculating the operating cost savings (i.e., through the final year in which products shipped are still operating).

Where:

$Ann_{x,r}$ = annualized value of the time-series x,
$f_{n,r}$ = factor to project a value n years ahead[c] with r discount rate,
$a_{30,r}$ = factor to annualize present values over a 30-year period with r discount rate.

Although DOE calculates annualized values, this does not imply that the time-series of cost and benefits from which the annualized values were determined would be a steady stream of payments.

10.6.2 Results for the Adopted Standards

The direct final rule associated with this TSD states that DOE is adopting amended energy conservation standards for residential dishwashers that correspond to TSL 2. Estimates of annualized benefits and costs for the adopted standards are shown in Table 10.6.1.

The Primary, Low Benefits, and High Benefits Estimates utilize forecasts of energy prices and housing starts from the *AEO2011* Reference case, Low Economic Growth case, and High Economic Growth case, respectively. In addition, incremental product costs reflect a medium declining trend in the Primary Estimate, a low price decline in the Low Benefits Estimate, and a high price decline in the High Benefits Estimate. See appendix 10C for discussion of analyses using alternative economic growth scenarios. And see appendix 8C and appendix 10B for discussion of the product price trends.

Table 10.6.1 Annualized Benefits and Costs of Amended Standards for Residential Dishwashers Sold in 2013–2047

	Discount Rate %	**Primary Estimate***	**Low Net Benefits Estimate***	**High Net Benefits Estimate***
		Monetized million 2010$/year		
Benefits				
Operating Cost Savings	7	53	48	59
	3	66	59	75
CO_2 Reduction at $4.9/t**	5	1.1	1.0	1.3
CO_2 Reduction at $22.3/t**	3	3.9	3.5	4.7
CO_2 Reduction at $36.5/t**	2.5	6.1	5.4	7.2

[c] *n* is the number of years between the "present" year and the compliance year.

	Discount Rate %	Primary Estimate*	Low Net Benefits Estimate*	High Net Benefits Estimate*
		Monetized million 2010$/year		
CO_2 Reduction at $67.6/t**	3	12.0	10.8	14.2
NO_X Reduction at $2,537/ton**	7	0.24	0.23	0.27
	3	0.26	0.24	0.30
Total†	7 plus CO_2 range	54 to 65	49 to 59	60 to 73
	7	57	52	64
	3	68 to 78	60 to 70	76 to 89
	3 plus CO_2 range	70	63	80
Costs				
Incremental Product Costs	7	46	44	43
	3	44	41	40
Total Net Benefits				
Total†	7 plus CO_2 range	8 to 19	6 to 16	17 to 30
	7	11	8	20
	3	24 to 35	19 to 29	37 to 49
	3 plus CO_2 range	27	22	40

* The results include benefits to consumers which accrue after 2047 from the dishwashers purchased from 2013 through 2047. Costs incurred by manufacturers, some of which may be incurred prior to 2013 in preparation for the rule, are indirectly included as part of incremental product costs. The Primary, Low Benefits, and High Benefits Estimates utilize forecasts of energy prices and housing starts from the AEO2011 Reference case, Low Estimate, and High Estimate, respectively. In addition, incremental product costs reflect a medium decline rate for projected product price trends in the Primary Estimate, a low decline rate for projected product price trends in the Low Benefits Estimate, and a high decline rate for projected product price trends in the High Benefits Estimate.

** The CO_2 values represent global values (in 2010$) of the social cost of CO_2 emissions in 2010 under several scenarios. The values of $4.9, $22.3, and $36.5 per ton are the averages of SCC distributions calculated using 5-percent, 3-percent, and 2.5-percent discount rates, respectively. The value of $67.6 per ton represents the 95th percentile of the SCC distribution calculated using a 3-percent discount rate. The value for NO_X (in 2010$) is the average of the low and high values used in DOE's analysis.

† Total Benefits for both the 3-percent and 7-percent cases are derived using the SCC value calculated at a 3-percent discount rate, which is $22.3/t in 2010 (in 2010$). In the rows labeled as "7% plus CO_2 range" and "3% plus CO_2 range"; the operating cost and NO_X benefits are calculated using the labeled discount rate, and those values are added to the full range of CO_2 values.

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