CHAPTER 10: NATIONAL IMPACT ANALYSIS

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CHAPTER 10. NATIONAL IMPACT ANALYSIS

10.1 INTRODUCTION

This chapter describes the U.S. Department of Energy (DOE)'s estimation of certain national impacts of potential energy conservation standards for small electric motors. Results described here include: (1) national energy savings (NES) from possible candidate standard levels (CSLs), (2) monetary value of the energy savings, (3) increased total installed costs of the considered appliances due to energy conservation standards, and (4) the net present value (NPV) of the difference between the value of energy savings and increased total installed costs.

DOE determined the NES and NPV for all of the CSLs considered for the three product classes of small electric motors: (1) polyphase motors, (2) capacitor-start induction-run (CSIR), and capacitor-start capacitor-run (CSCR) motors. DOE 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/commercial/small_electric_motors.html). The spreadsheet model that contains the national impact analysis (NIA), combines the calculations for determining the NES and NPV as well as input from the relevant shipments model. The shipments analysis (see preliminary Technical Support Document (TSD) chapter 9) provides a detailed description of the shipments models that DOE used to forecast future purchases of the considered products.

10.2 NATIONAL ENERGY SAVINGS

10.2.1 National Energy Savings Definition

DOE calculates annual *NES* in each year as the difference between energy consumption of the product stock using the average unit energy consumption (*UEC*) of the stock in the base case (without new standards) or in a case with new standards.

$$NES(y)_{class} = AffStock(y)_{class} \times \left(UEC(y)_{base,class} - UEC(y)_{std,class}\right)$$

For the above expressions, DOE defined the various quantities as follows:

$AffStock(y)_{class}$ = the stock of equipment sold after the year of the standard that is still in operation in year y (affected stock)

$UEC(y)_{base\ class}$ = the unit energy consumption in the base case in year *y*

$UEC(y)_{std.\ class}$ = the unit energy consumption in the standard case in year *y*

The affected stock in year *y* is given by

$$AffStock(y)_{class} = \sum_{i=stdyr}^{y} S(i)_{class} \times Surv(y-i)_{class}$$

The stock in year *y* is dependent on the number of shipments $S(y)_{\text{class}}$ in past years, multiplied by the survival function *Surv(v)*, the fraction of shipments surviving till age *v* (vintage). Only shipments occurring after the year of standard (*stdyr*) are considered for the calculation of NES, since shipments before this date will not be affected by the standard, and thus will produce no savings. The variables $UEC_{base,class}$ and $UEC_{std,class}$ are the average unit energy consumption of equipment sold in the base and standards cases, respectively.

Cumulative energy savings are the sum over a defined time period (2015 to 2045 for water heaters, 2013 to 2045 for the other products) of the annual national energy savings:

$$NES_{cum} = \sum_{y=stdyr}^{2045} NES(y)$$

The stock of products is dependent on annual shipments and the lifetime of the products.

10.2.2 National Energy Savings Inputs

Table 10.2.1 lists the inputs for the determination of national energy savings.

Table 10.2.1 National Energy Saving Inputs

Annual Energy Consumption per Unit (*UEC*)
Shipments
Equipment Stock ($STOCK_V$)
National Annual Energy Consumption (*AEC*)
Site-to-Source Conversion Factor (*src_conv*)

10.2.2.1 Annual Energy Consumption per Unit

For each of the considered products, DOE presented the per-unit annual energy consumption as a function of product energy efficiency in the energy use determination (see preliminary TSD chapter 6), and the life-cycle cost and payback period analysis (see preliminary TSD chapter 8). Because the per-unit annual energy consumption is directly dependent on energy efficiency, DOE used the base case and standards case shipment-weighted energy efficiencies presented above in section 10.2, in combination with the annual energy use data presented in the life-cycle cost and payback period analysis (see preliminary TSD chapter 8), to estimate the shipment-weighted average annual per-unit energy consumption under the base case and standards cases.

Table 10.2.2 Small Electric Motors: Shipment-Weighted Average Per-Unit Annual Energy Consumption in 2015

Product Class		Base Case	Candidate Standard Level				
			1	2	3	4	5
Polyphase	Efficiency (%)	76.4	84.0	85.5	86.5	88.0	90.0
	Annual Energy Use (kWh/yr)*	430.4	265.0	235.9	217.1	189.7	154.6
Single Phase -CSCR	Efficiency (%)	63.3	70.9	73.6	75.4	78.2	81.8
	Annual Energy Use (kWh/yr)	392.7	278.1	242.7	220.5	189.2	150.6
Single Phase -CSIR	Efficiency (%)	67.9	80.2	82.1	83.3	85.2	87.6
	Annual Energy Use (kWh/yr)	479.8	250.2	221.7	203.3	176.8	143.2

* Kilowatt hours per year.

For some types of equipment, a significant “rebound effect” can occur when more efficient equipment is used more intensely in response to the economic savings from energy efficiency. Accounting for a significant rebound effect will decrease energy savings compared to a scenario with no rebound effect. Small electric motors are predominantly components of larger pieces of equipment or an integrated production process. Typically, energy losses from inefficient operation of the larger equipment or process that contains a small electric motor are much greater than losses due to inefficiencies of the individual motor. In addition, consumers rarely have direct control over the intensity of motor operation. Given these considerations and a lack of data indicating a rebound effect for small electric motors, DOE assumed that there is no significant rebound effect for this equipment.

10.2.2.2 Shipments and Equipment Stock

An extensive description of the methodology for conducting and generating the shipments forecasts for each of the considered products can be found in the shipments analysis (see preliminary TSD chapter 9). The product stock in a given year is the number of products shipped from earlier years that survive in the given year. The NIA models keep track of the number of units shipped each year. DOE assumes that the 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. Please refer to the life cycle cost analysis (see preliminary TSD chapter 8, section 8.2.4 “Motor Lifetime”) for further details on the motor lifetimes that DOE used in its analysis.

10.2.2.3 National Annual Energy Consumption

The national annual energy consumption (AEC) is calculated in the base case only and is the product of the annual energy consumption per unit and the number of units of each vintage:

$$AEC(y)_{class} = UEC_{base,class} \times Stock(y)_{class}$$

Where:

$UEC_{base\ class}$	=	the unit energy consumption in the base case
$Stock(y)_{class}$	=	the stock of equipment in year *y*

10.2.2.4 Energy Site-to-Source Conversion Factors

In determining national annual energy savings, DOE initially calculated the annual energy consumption at the site (e.g., for electricity, the energy in kWh consumed at the household). It then calculated primary (source) energy savings from site 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 the multiplicative factor used for converting site energy consumption into primary or source energy consumption, expressed in quads.

DOE used annual site-to-source conversion factors based on the version of the National Energy Modeling System (NEMS) that corresponds to U.S. DOE/Energy Information Administration (EIA)'s *Annual Energy Outlook 2008 (AEO2008).*[1] The factors used are marginal values, which represent the response of the system to an incremental decrease in consumption. For electricity, the conversion factors vary over time, due to projected changes in generation sources (i.e., the power plant types projected to provide electricity to the country). NEMS outputs stop in 2030; DOE assumed that conversion factors remain constant at 2030 values throughout the remainder of the forecast. Figure 10.2.1 shows the site-to-source conversion factors between 2005 and 2030 for electricity.

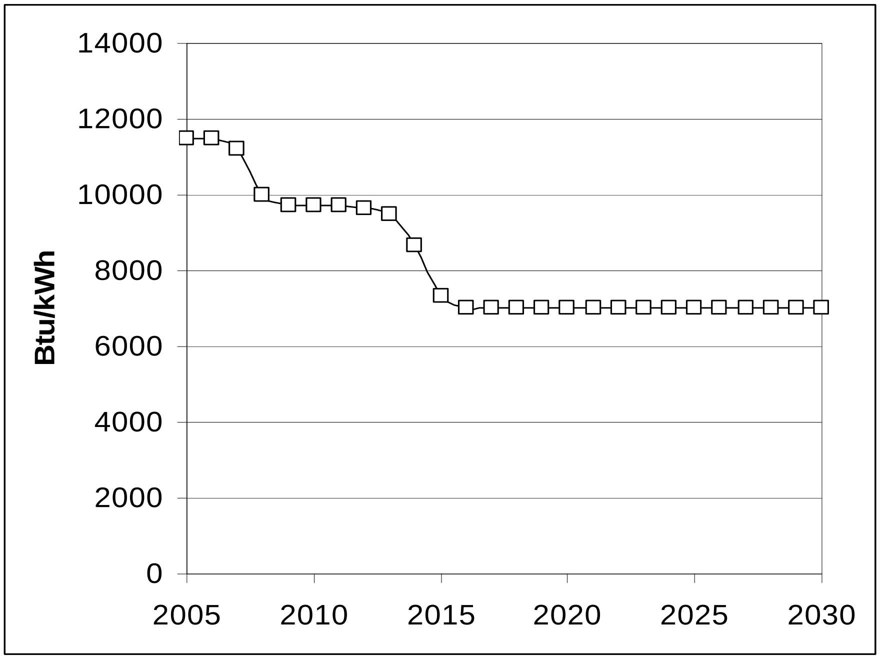

Figure 10.2.1 Site-to-Source Conversion Factors for Electricity

10.3 NET PRESENT VALUE

10.3.1 Net Present Value Definition

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

$$NPV = \sum_{y} \left(S(y) - C(y) \right) \times DF(y)$$

Where:

S(y) = value of operating cost savings (including energy, repair, and maintenance costs) in year *y*, and
C(y) = value of increased total installed costs (including products and installation).
DF(y) = discount factor in each year,

DOE calculated the total annual operating cost savings by multiplying the number or stock of the given product (by vintage) by its per-unit operating cost savings (also by vintage). DOE calculated the total annual installed cost increases by multiplying the number or stock of the given product (by vintage) by its per-unit total installed cost increase (also by vintage). The calculation of the annual operating costs savings and total annual installed cost increases is represented with the following equations:

$$OCS(y) = \sum UOCS(y) \times AffStock(y)$$

$$TIC\ (y) = \sum UTIC(y) x S(y)$$

Where:

OCS =	total annual operating cost savings each year summed over vintages of the affected product stock, *AffStock(y)*,
TIC =	total annual installed cost increases each year summed over vintages of the affected product stock, *AffStock(y)*,
S(y)=	stock of product (millions of units) of vintage *V* surviving in the year for which DOE calculated annual energy consumption,
UOCS(y) =	annual operating cost savings per unit in year y,
UTIC(y) =	annual total installed cost increase per unit in year y,
y =	year in the forecast.

DOE calculated a discount factor from the 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.

10.3.2 Net Present Value Inputs

Table 10.3.1 summarizes the inputs to the net present value calculation.

Table 10.3.1 Net Present Value Inputs

Total Installed Cost per Unit
Annual Operating Cost Savings per Unit
Total Annual Installed Cost Increases
Total Annual Operating Costs
Discount Factor
Present Value of Costs
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 each standards case and base 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.

The *total annual operating cost savings* are equal to the change in the annual operating costs (difference between base case and each standards case) per unit multiplied by the shipments forecasted in the standards case. The annual operating cost includes energy, repair, and maintenance costs, presented in the life-cycle cost and payback period analysis (see preliminary TSD chapter 8).

10.3.2.1 Total Installed Cost per Unit

For each of the considered products, DOE first presented the per-unit total installed cost as a function of product energy efficiency in the life-cycle cost and payback period analysis. (See preliminary TSD chapter 8.) Because the per-unit total annual installed cost is directly dependent on energy efficiency, DOE used the base case and standards case shipment-weighted energy efficiencies presented above in section 10.2, in combination with the total installed costs presented in the life-cycle cost and payback period analysis (see preliminary TSD chapter 8), to estimate the shipment-weighted average annual per-unit total installed cost under the base case and standards cases.

Table 10.3.2 Small Electric Motors: Shipment-Weighted Average Per-Unit Total Installed Cost in 2015

Product Class		Base Case	Candidate Standard Level				
			1	2	3	4	5
Polyphase	Efficiency (%)	76.4	84.0	85.5	86.5	88.0	90.0
	Total Installed Cost (2007$)	$482	$523	$548	$663	$986	$2,619
Single Phase -CSCR	Efficiency (%)	63.3	70.9	73.6	75.4	78.2	81.8
	Total Installed Cost (2007$)	$490	$510	$526	$542	$579	$977
Single Phase -CSIR	Efficiency (%)	67.9	80.2	82.1	83.3	85.2	87.6
	Total Installed Cost (2007$)	$532	$561	$578	$598	$656	$1,402

As noted above in section 10.2, DOE assumed that forecasted energy efficiencies in the base case and standards cases remain frozen at the energy efficiency levels in the effective year. Therefore, because the per-unit total installed costs are a function of energy efficiency, DOE held the values shown above constant over the forecast period.

10.3.2.2 Annual Operating Cost Savings per Unit

The per-unit annual operating cost includes the energy, repair, and maintenance costs. DOE determined the per-unit annual operating cost savings by taking the per-unit annual energy consumption savings developed for each product and multiplying it by the appropriate energy price.

DOE forecasted the per-unit annual energy consumption for the base case and each standards case by freezing the consumption at levels estimated for the effective year.

DOE forecasted energy prices based on EIA's *AEO2008*. The energy prices and energy price trends are described in Chapter 8.

10.3.2.3 Total Annual Installed Cost Increases

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. The equation for determining the total annual installed cost increase for a given standards case was shown in section 10.4.1 and is repeated below.

$$TIC\ (y) = \sum UTIC(y) x S(y)$$

10.3.2.4 Total Annual Operating Cost Savings

The total annual operating cost savings 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. The equation for determining the total annual operating cost savings for a given standards case was shown above and is repeated below.

$$OCS(y) = \sum UOCS(y) \times AffStock(y)$$

10.3.2.5 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. It used these discount rates 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 2007.

10.3.2.6 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 the standards case and base case), discounted to the present, and summed for the time period over which DOE is considering the installation of products (i.e., from the effective date of energy conservation standards through 30 years later).

The increase in total installed cost refers to both product cost and installation cost associated with the higher energy efficiency of products purchased in the standards case compared to the base case. 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.

10.3.2.7 Present Value of Savings

The present value of operating cost savings is the annual operating cost savings (i.e., the difference between the base case and standards case) discounted to the present, and summed over the period from the effective date to the time when the last unit installed is retired from service.

Savings are decreases in operating costs (including energy, repair, and maintenance costs) associated with the higher energy efficiency of products purchased in a 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. Equipment consumes energy over its entire lifetime, and for units purchased in the last year, the consumption includes energy consumed until the unit is retired from service.

10.4 NATIONAL ENERGY SAVINGS AND NET PRESENT VALUE RESULTS

The NIA model provides estimates of the NES and NPV due to various candidate standards levels. The inputs to the NIA model have been 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/commercial/small_electric_motors.html*). Details and instructions for using the spreadsheet are provided in Appendix 10-A, User Instructions for National Impact Analysis Spreadsheet.

Table 10.4.1 summarizes the inputs to the NIA model.

Table 10.4.1 National Energy Savings and Net Present Value Inputs

Input	Data Description
Shipments	Annual shipments from shipments model. (See Chapter 9)
Effective Date of Standard	2015
Base Case Forecasted Energy Efficiencies	Shipment-weighted unit energy consumption (UEC), based on efficiency and hours of operation
Standards Case Energy Efficiencies	The UEC for each standards case, based on efficiency and hours of operation.
Annual Energy Consumption per Unit	Annual weighted-average values are a function of shipment-weighted UEC.
Total Installed Cost per Unit	Annual weighted-average values are a function of efficiency level.
Energy Cost per Unit	Annual weighted-average values are a function of the annual UEC and energy prices. (See Chapter 8 for energy prices)
Repair Cost and Maintenance Cost per Unit	Annual values are a function of efficiency level. (See Chapter 8)
Trend in Energy Prices	Based on EIA *AEO2008* forecasts (to 2030) and extrapolation to 2045. (See Chapter 8)
Energy Site-to-Source Conversion Factor	Conversion varies yearly and is generated by DOE/EIA's NEMS* program (a time series conversion factor; includes electric generation, transmission, and distribution losses).
Discount Rate	3 percent and 7 percent real.
Present Year	Future expenses are discounted to year 2007.

* Chapter 13 on the Utility Impact Analysis and the Environmental Assessment Report provide more detail on NEMS.

10.4.2 National Energy Savings Results

The following sections provide NES results for the standards cases analyzed for the three product classes. NES results are cumulative to 2045 and are shown as primary energy 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 analysis.

Tables 10.4.2 through 10.4.5 show the NES results for the candidate standard levels (CSLs) analyzed for small electric motors. There is a steady increase in energy savings with increasing standard level.

Table 10.4.2 Polyphase Motors: Cumulative National Energy Savings Results

Candidate Standard Level	Efficiency (%)	National Energy Savings (quads)*		
		No Discount Rate	3% Discount Rate	7% Discount Rate
1	84.0	0.217	0.107	0.047
2	85.5	0.255	0.126	0.056
3	86.5	0.280	0.139	0.061
4	88.0	0.315	0.156	0.069
5	90.0	0.362	0.179	0.079

* Quadrillion British thermal units.

Table 10.4.3 Capacitor-Start Induction-Run Motors: Cumulative National Energy Savings Results

Candidate Standard Level	Efficiency (%)	National Energy Savings (quads)		
		No Discount Rate	3% Discount Rate	7% Discount Rate
1	70.9	1.095	0.552	0.249
2	73.6	1.434	0.723	0.326
3	75.4	1.646	0.830	0.375
4	78.2	1.946	0.982	0.443
5	81.8	2.314	1.167	0.527

Table 10.4.4 Capacitor-Start Capacitor-Run Motors: Cumulative National Energy Savings Results

Candidate Standard Level	Efficiency (%)	National Energy Savings (quads)		
		No Discount	3% Discount Rate	7% Discount Rate
1	80.2	0.114	0.058	0.026
2	82.1	0.129	0.065	0.029
3	83.3	0.138	0.070	0.032
4	85.2	0.151	0.076	0.035
5	87.6	0.168	0.085	0.038

10.4.3 Annual Costs and Savings

To illustrate the basic inputs to the NPV calculations, Figure 10.4.1 presents the non-discounted annual installed cost increases and annual operating cost savings at the national level for CSL 2 for polyphase small electric motors. 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 sum of 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 can create figures like the one shown below for each of the considered products' standard cases.

Figure 10.4.1 Non-Discounted Annual Installed Cost Increases and Annual Operating Cost Savings for Polyphase Small Electric Motors, Candidate Standard Level 2

10.4.4 Net Present Value Results

The following sections provide NPV results for the candidate standards levels considered for the product classes of each considered product. Results are cumulative and are shown as the discounted value of the net 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 analysis.

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 evaluates the impact of energy conservation standards. Savings are decreases in operating costs associated with the higher energy efficiency of products purchased in the standards cases compared to the base case. Total operating cost savings 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 up through the final year (2045), the operating cost includes energy consumed until the last unit is retired from service.

Tables 10.4.5 through 10.4.7 show the NPV results for the candidate standard levels analyzed for each small electric motor product class. The highest CSL that has a positive NPV for both discount rates is CSL 2 for polyphase motors, CSL 3 for CSIR motors, and CSL 4 for CSCR motors

Table 10.4.5 Polyphase Motors: Cumulative Net Present Value Results

Candidate Standard Level	Efficiency (%)	Net Present Value	
		3% Discount Rate *billion 2007$*	**7% Discount Rate** *billion 2007$*
1	84.0	0.59	0.23
2	85.5	0.46	0.16
3	86.5	-0.87	-0.48
4	88.0	-4.81	-2.38
5	90.0	-25.39	-12.29

Table 10.4.6 Capacitor-Start Induction-Run Motors: Cumulative Net Present Value Results

Candidate Standard Level	Efficiency (%)	Net Present Value	
		3% Discount Rate *billion 2007$*	**7% Discount Rate** *billion 2007$*
1	70.9	3.79	1.51
2	73.6	3.86	1.45
3	75.4	3.27	1.10
4	78.2	0.63	-0.26
5	81.8	-43.31	-21.62

Table 10.4.7 Capacitor-Start Capacitor-Run Motors: Cumulative Net Present Value Results

Candidate Standard Level	Efficiency (%)	Net Present Value	
		3% Discount Rate *billion 2007$*	**7% Discount Rate** *billion 2007$*
1	80.2	0.47	0.19
2	82.1	0.44	0.18
3	83.3	0.37	0.14
4	85.2	0.10	0.00
5	87.6	-4.30	-2.14

REFERENCES

1. U.S. Department of Energy - Energy Information Administration, *Annual Energy Outlook 2008 (Revised Early Release) with Projections to 2030*, 2008. Washington, DC.