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 operating cost savings, (3) increased total installed costs of the considered products due to energy conservation standards, and (4) the net present value (NPV) of the difference between the value of operating cost savings and increased total installed costs.

DOE determined the NES and NPV for all of the energy efficiency levels considered for the three equipment categories of small electric motors considered for this rulemaking: (1) polyphase motors, (2) capacitor-start induction-run (CSIR), and (3) capacitor-start capacitor-run (CSCR) motors. DOE built a combined NES and NPV model for CSIR and CSCR motors, reflecting the fact that these motors may be used interchangeably in many applications. This model incorporates the shipments market share model for these motors detailed in Section 9.4. DOE performed all calculations for each of the considered equipment categories using a Microsoft Excel spreadsheet model, which is accessible on the Internet (<http://www1.eere.energy.gov/buildings/appliance_standards/>). The spreadsheet models that contain the national impact analysis (NIA) combine the calculations for determining the NES and NPV with the relevant shipments models. The shipments analysis (see chapter 9) provides a detailed description of the shipments models that DOE used to forecast future purchases of the considered equipment.

The small electric motors covered by this rulemaking and analysis constitute a fraction of all small electric motors in use throughout the United States. In residential and commercial contexts, most motor energy is used by appliances or systems covered by other existing efficiency standards (such as refrigerators and air conditioners). DOE drew upon analysis conducted in 1999[1] to conclude that small electric motors less than or equal to 2 horsepower use approximately 300 TWh per year in the residential sector and 150 TWh per year in the commercial sector. This energy consumption includes the useful work conducted by the motors in addition to losses. DOE assumed that energy use by small motors in industrial and agricultural applications totals approximately half the use in commercial applications, or roughly 75 TWh per year. This analysis implies that total annual electricity use by small electric motors is approximately 525 TWh. Of this, DOE's 1999 analysis indicates that roughly 12% of residential small motor energy use and 25% of commercial small motor energy use are due to motors in applications not covered by other efficiency standards. DOE assumed that 95% of industrial and agricultural small motor energy use is due to motors not covered by other efficiency standards. This implies that motor energy use (including useful work and losses) by small electric motors not covered by other efficiency standards is approximately 145 TWh per year. DOE's national energy savings analysis indicates that electricity use by motors covered by this rulemaking is approximately 40 TWh per year (including useful work and losses). This is approximately 27% of the energy use by small electric motors not covered by other standards, and approximately 7% of the energy use by all small electric motors.

10.2 BASE AND STANDARDS CASE EFFICIENCY DISTRIBUTIONS

This section describes the method DOE used to forecast the energy efficiencies of considered equipment under the base case and each of the potential standards cases. It provides efficiency distributions for the three equipment categories of small electric motors considered for this rulemaking.

10.2.1 Base Case Efficiency Distribution

DOE did not have access to motor shipment data as a function of efficiency for any product classes. DOE studied manufacturer catalogs to determine the current distribution of motor efficiency among the levels considered in this analysis. Not all motors listed in manufacturer catalogs included information regarding the motor's full-load or nominal (NEMA) efficiency. Therefore, the Department used the number of models with a published efficiency rating as a proxy for the number of shipments. DOE did not develop separate efficiency distributions for each product class. Instead, it used a single efficiency distribution for each motor category (polyphase, CSIR, and CSCR), derived from the distribution of models within each category.

Table 10.2.1 shows DOE's estimated current efficiency distribution for polyphase, CSIR, and CSCR motors. DOE assumed that, in the absence of standards (the base case), this distribution would remain fixed over the analysis period.

Table 10.2.1 Base Case Efficiency Distributions

Efficiency Level	Market Share (%)		
	Polyphase	CSIR	CSCR
Baseline	54.0	40.0	37.0
1	6.0	30.0	33.0
2	13.0	13.0	4.0
3	7.0	15.0	11.0
4	12.0	2.0	11.0
5	5.0	0.0	0.0
6	3.0	0.0	4.0
7	0.0	0.0	0.0
8	0.0	-	0.0

10.2.2 Standards Case Efficiency Distributions

DOE used a simple “roll up” approach to forecast efficiency distributions in the case of standards. That is, DOE assumed that motor customers who would have purchased motors with a rated efficiency below that of the minimum efficiency required by the standard would instead purchase motors which exactly met the standard. Customers who would have purchased motors above the minimum required by the standard are unaffected, so the market shares in those efficiency levels remain unchanged.

Tables 10.2.2, 10.2.3, and 10.2.4 show the resulting efficiency distributions the Department used for each standards case. For example, in the case of a standard for polyphase motors at efficiency level 1, the 54 percent of purchases at the baseline efficiency level would roll up to level 1, yielding a total share of 60 percent, while the shares above level 1 are unaffected.

Table 10.2.2 Polyphase Motor Efficiency Market Shares in the Base and Standards Cases

Standard Case Efficiency Level	Market Share (%)								
	Baseline	Effic. Level 1	Effic. Level 2	Effic. Level 3	Effic. Level 4	Effic. Level 5 (4b)	Effic. Level 6	Effic. Level 7	Effic. Level 8
Baseline	54.0	6.0	13.0	7.0	12.0	5.0	3.0	0.0	0.0
1	0.0	60.0	13.0	7.0	12.0	5.0	3.0	0.0	0.0
2	0.0	0.0	73.0	7.0	12.0	5.0	3.0	0.0	0.0
3	0.0	0.0	0.0	80.0	12.0	5.0	3.0	0.0	0.0
4	0.0	0.0	0.0	0.0	92.0	5.0	3.0	0.0	0.0
5 (4b)	0.0	0.0	0.0	0.0	0.0	97.0	3.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0

Table 10.2.3 CSIR Motor Efficiency Market Shares in the Base and Standards Cases

Standard Case Efficiency Level	Market Share (%)							
	Baseline	Effic. Level 1	Effic. Level 2	Effic. Level 3	Effic. Level 4	Effic. Level 5	Effic. Level 6	Effic. Level 7
Baseline	40.0	30.0	13.0	15.0	2.0	0.0	0.0	0.0
1	0.0	70.0	13.0	15.0	2.0	0.0	0.0	0.0
2	0.0	0.0	83.0	15.0	2.0	0.0	0.0	0.0
3	0.0	0.0	0.0	98.0	2.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0

Table 10.2.4 CSCR Motor Efficiency Market Shares in the Base and Standards Cases

Standard Case Efficiency Level	Market Share (%)								
	Baseline	Effic. Level 1	Effic. Level 2	Effic. Level 3	Effic. Level 4	Effic. Level 5	Effic. Level 6	Effic. Level 7	Effic. Level 8
Baseline	37.0	33.0	4.0	11.0	11.0	0.0	4.0	0.0	0.0
1	0.0	70.0	4.0	11.0	11.0	0.0	4.0	0.0	0.0
2	0.0	0.0	74.0	11.0	11.0	0.0	4.0	0.0	0.0
3	0.0	0.0	0.0	85.0	11.0	0.0	4.0	0.0	0.0
4	0.0	0.0	0.0	0.0	96.0	0.0	4.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	96.0	4.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0

10.3 NATIONAL ENERGY SAVINGS

10.3.1 National Energy Savings Definition

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

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

Where:

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

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

$UEC(y)_{std.\ class}$ = 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 until age *v* (vintage). Only shipments occurring after the effective year of the 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.

Cumulative energy savings are the sum of the annual national energy savings over a defined time period (in this case, from 2015 until 2045):

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

10.3.2 National Energy Savings Inputs

Table 10.2.1 lists the inputs for the determination of national energy savings. The following sections discuss each input.

Table 10.3.1 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*)

10.3.2.1 Annual Energy Consumption per Unit

For each of the representative product classes, DOE presented the per-unit annual energy consumption as a function of equipment energy efficiency in the energy use determination (see chapter 7). 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 energy use determination (see chapter 7), to estimate the shipment-weighted average annual per-unit energy consumption under the base case and standards cases for each of the three representative product classes (4-pole 1 hp polyphase, ¾ hp CSCR, and ½ hp CSIR).

DOE also used the power factor of its motor designs in the representative product classes to determine the shipment-weighted reactive power requirements of motors of varying efficiency. Reactive power is measured in Kilovolt Amperes-reactive (kVAr). Table 10.3.2 shows the shipment-weighted annual energy use and reactive power for each of these product classes.

Table 10.3.2 Small Electric Motors: Shipment-Weighted Average Per-Unit Annual Energy Consumption in 2015 for Representative Product Classes

Product class		Base Case	Efficiency Level							
			1	2	3	4	5	6	7	8
Polyphase 1 HP, 4 poles	Efficiency (%)	74.0	76.1	77.7	79.4	80.1	82.6	84.4	85.3	87
	Annual Energy Use (kWh/yr)*	356	336	316	287	277	227	202	186	165
	Reactive Power (kVAr)	0.98	0.93	0.91	0.84	0.84	0.83	0.80	0.78	0.87
Single Phase – CSIR, ½ HP, 4 poles	Efficiency (%)	59.0	62.2	64.5	66.7	71.5	72.7	74.0	78.4	-
	Annual Energy Use (kWh/yr)*	534	502	464	421	335	310	279	219	-
	Reactive Power (kVAr)	0.84	0.82	0.79	0.72	0.61	0.56	0.61	0.53	-
Single Phase – CSCR, ¾ HP, 4 poles	Efficiency (%)	72.0	75.7	80.0	82.2	83.2	84.5	85.2	87.1	88.4
	Annual Energy Use (kWh/yr)*	378	354	277	244	251	239	217	185	154
	Reactive Power (kVAr)	0.58	0.50	0.40	0.39	0.17	0.17	0.12	0.12	0.08

* Kilowatt hours per year, losses only.

DOE used the loss scaling relations detailed in chapter 5 to scale the losses from the representative product class within each motor category to each of the other product classes. In this way, the Department was able to develop a shipment-weighted sum of all annual motor losses across each motor category (see section 10.3.2.3).

For some types of equipment, a "rebound effect" can occur when more efficient equipment is used more intensely in response to the economic savings from energy efficiency. Accounting for a 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, customers 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.

10.3.2.2 Shipments and Equipment Stock

An extensive description of the methodology for conducting and generating the shipments forecasts for each of the considered product classes can be found in chapter 9. The equipment stock in a given year is the number of motors 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 motors 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 chapter 8) for further details on the motor lifetimes that DOE used in its analysis. In the NIA, DOE used shipment-weighted average energy use, corresponding roughly to average hours of operation. Therefore, in the NIA there is no correlation between annual hours of operation and motor lifetime, as there is in the life-cycle cost analysis.

The survival function used in the NIA for each motor category is the aggregate survival function for motors within that category. Because DOE's forecasts of shipments are based on economic drivers, rather than explicit replacements and growth within a particular customer base, motors with shorter lifetimes constitute a larger fraction of motor shipments than they constitute of the installed motor stock. DOE uses the shipment-weighted annual energy consumption, which accounts for the fact that these motors use a larger fraction of the energy than they constitute of the installed motor stock.

10.3.2.3 National Annual Energy Consumption

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

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

Where:

UEC_{class} = the unit energy consumption for a given *class*

$Stock(y)_{class}$ = the stock of equipment in year y

The Department summed the UEC for each product class within each motor category to determine the total energy used for each category of motors in each year during the analysis period.

10.3.2.4 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, commercial building, farm, or industrial facility). 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 the *American Recovery and Reinvestment Act* scenario of the U.S. DOE/Energy Information Administration (EIA)'s *Annual Energy Outlook 2009 (AEO2009).*[2] 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 period. Figure 10.2.1 shows the site-to-source conversion factors between 2005 and 2030 for electricity.

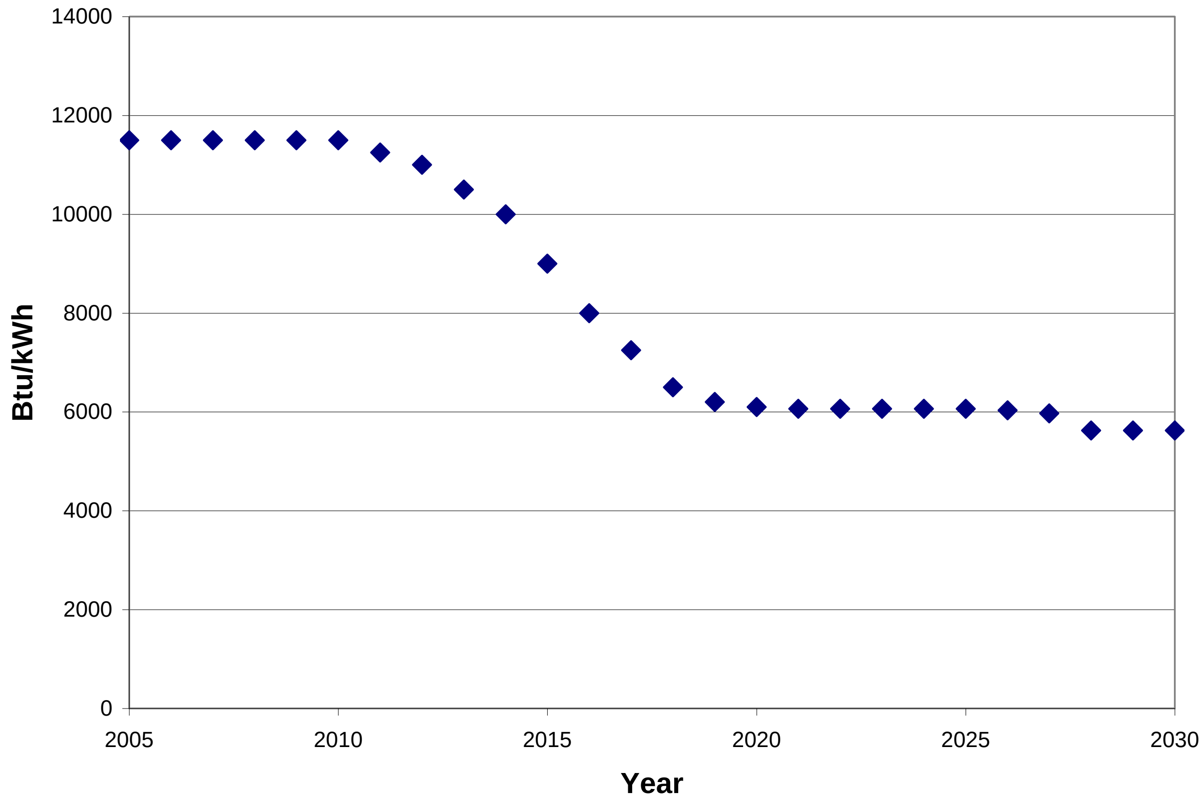

Figure 10.3.1 Site-to-Source Conversion Factors for Electricity

DOE also developed an estimate of the energy losses in the transmission and distribution system due to the reactive power needed by small electric motors. Reactive power is not consumed within the motor, but the necessary power must be generated by utilities and is manifested as larger currents in the transmission and distribution system than would be required if every load required only active power (that is, had a power factor of 1.0). The conversion factor between the reactive power (in giga-VAr) required by motors and the site requirements (primary energy) for that reactive power is:

$$PE_{reactive} = \left(RP \times S2S_{active} \times Loss_{trans} \times AvgHours\right) \Big/ LossAdj_{mid}$$

Where:

$PE_{reactive}$ = annual primary energy, in quads, required to meet the reactive power load,
RP = reactive load, in GVAr, required by motors,
$S2S_{active}$ = the site-to-source conversion factor for active power,
$Loss_{trans}$ = 6.33%, the national average energy loss in transmission and distribution,
$AvgHours$ = the average annual hours of motor operation, and

LossAdj$_{mid}$ = a conversion factor, equal to $\sqrt{1+Loss_{trans}}$, which accounts for the assignment of transmission and distribution losses to the midpoint of the route between site and source.

10.4 NET PRESENT VALUE

10.4.1 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 equipment purchase cost 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 class (by vintage) by its per-unit operating cost (also by vintage) in the base case and standards case, and subtracting to calculate the savings. DOE calculated the total annual installed cost increases by multiplying the number or stock of the given product class (by vintage) by its per-unit total installed cost (also by vintage) in the base case and standards case, and subtracting to calculate the increase. The calculation of the annual operating costs savings and total annual installed cost increases is represented with the following equations:

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

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

Where:

OCS = total annual operating cost savings each year summed over vintages of the affected equipment stock, *AffStock(y)*,
ΔTIC = total annual installed cost increases each year summed over vintages of the affected equipment stock, *AffStock(y)*,
S(y)= stock of motors 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, and
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 ─ 2009 for all NPV quantities presented in this TSD) 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 Net Present Value Inputs

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

Table 10.4.1 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.

The *total annual operating cost savings* are equal to the difference in the annual operating costs between the base case and each standards case, calculated by multiplying the cost to operate each unit by the shipments forecasted in the base and standards cases. The annual operating cost includes energy, repair, and maintenance costs.

10.4.2.1 Total Installed Cost per Unit

For each of the representative product classes, DOE presented the per-unit total installed cost as a function of equipment energy efficiency in the life-cycle cost and payback period analysis (see 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, to estimate the shipment-weighted average annual per-unit total installed cost under the base case and standards cases for each of the three representative product classes. These averages are shown in Table 10.4.2. As in the life-cycle cost analysis, DOE assumed that 20% of the motors were space-constrained.

Table 10.4.2 Small Electric Motors: Shipment-Weighted Average Per-Unit Total Installed Cost in 2015 for Representative Product Classes

Product class		Base Case	Efficiency Level							
			1	2	3	4	5	6	7	8
Polyphase 1 HP, 4 poles	Efficiency (%)	74.0	76.1	77.7	79.4	80.1	82.6	84.4	85.3	87.0
	Total Installed Cost (2008$)	$536	$543	$547	$556	$563	$591	$755	$770	$3,450
Single Phase – CSIR, ½ HP, 4 poles	Efficiency (%)	59.0	62.2	64.5	66.7	71.5	72.7	74.0	78.4	-
	Total Installed Cost (2008$)	$501	$504	$509	$511	$528	$548	$592	$996	-
Single Phase –, CSCR, ¾ HP, 4 poles	Efficiency (%)	72.0	75.7	80.0	82.2	83.2	84.5	85.2	87.1	88.4
	Total Installed Cost (2008$)	$570	$573	$594	$602	$613	$630	$669	$696	$1,482

DOE used the price scaling relations derived in its life-cycle cost analysis (see chapter 8) to develop shipment-weighted average motor installed costs for each product class. This allowed the Department to weight the total installed cost increases by the distribution of motor shipments across product classes.

As noted in section 10.2, DOE assumed that forecasted energy efficiencies in the base case and standards cases remain constant 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 installed cost constant over the forecast period.

10.4.2.2 Annual Operating Cost Savings per Unit

The per-unit annual operating cost includes the energy, reactive power, 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 class and multiplying it by the appropriate energy and reactive power prices.

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

DOE forecasted energy prices based on the *American Recovery and Reinvestment Act* scenario of EIA's *AEO2009*. The energy prices and energy price trends are described in chapter 8.

10.4.2.3 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 shipped each 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 here:

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

10.4.2.4 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. The equation for determining the total annual operating cost savings for a given standards case was shown in section 10.4.1 and is repeated here:

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

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. 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 2009.

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

The increase in total installed cost refers to both equipment purchase 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 between the total installed cost for all new products purchased each year in the base case and in the standards case. (DOE assumed that total motor sales were inelastic – see section 9.4.1 – so that total shipments are unchanged between the base and standards cases.)

10.4.2.7 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 equipment 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.

10.5 TRIAL STANDARD LEVELS

DOE generated NES and NPV results based on trial standard levels (TSLs). The TSLs are based on the following: (1) efficiency levels corresponding to designs of motors in representative product classes, characterized in the engineering analysis, (2) the efficiency level identified with the maximum efficiency, and (3) a combination of efficiency levels for different product categories that have potentially positive impacts on consumers and the Nation. The efficiency levels considered were those analyzed in the engineering analysis (chapter 5), for which the Department designed motors utilizing technologically feasible design options. The Department analyzed the national impacts of a set of trial standard levels (TSLs) for polyphase motors and a set of TSLs for capacitor-start motors.

10.5.1 Polyphase Small Electric Motors

The polyphase TSLs, listed in Table 10.5.1, correspond to the efficiency levels described in the engineering analysis (chapter 5) and life-cycle cost analysis (chapter 8). DOE used the price and energy use relations developed in the engineering and LCC analyses to assign costs and efficiencies to motors in product classes other than the representative product class (4 poles, 1 horsepower).

Table 10.5.1 Trial Standard Levels for Polyphase Small Electric Motors

Trial Standard Level	Efficiency Level	4 pole, 1 Hp Full Load Efficiency %
1	1	76.1
2	2	77.7
3	3	79.4
4	4	80.1
4b	5	82.6
5	6	84.4
6	7	85.3
7**	8	87.0

*Standard levels are expressed in terms of full-load efficiency.
** Maximum technologically feasible efficiency level

10.5.2 Capacitor-Start Small Electric Motors

Trial standard levels for capacitor-start motors are composed of efficiency level standards for both CSIR and CSCR motors. The Department chose to analyze a subset of all possible combinations of CSIR and CSCR efficiency levels as its TSLs for capacitor-start motors. Table 10.5.2 shows the combinations the Department selected.

Table 10.5.2 Trial Standard Levels for Capacitor-Start Small Electric Motors

Trial Standard Level	CSIR Efficiency Level	CSIR 4 pole 0.50 Hp Full Load Efficiency %	CSCR Efficiency Level	CSCR 4 pole 0.75 Hp Full Load Efficiency %
1	4	71.5	2	80.0
2	4	71.5	3	82.2
3	5	72.7	3	82.2
4	6	74.0	4	83.2
5	6	74.0	3	82.2
6**	7	78.4	8	88.4
7	7	78.4	3	82.2
8	7	78.4	7	87.1

*Standard Levels are expressed in terms of full-load efficiency.
** Maximum technologically feasible efficiency levels

Trial standard level 1 corresponds to an efficiency level combination considered by motor manufacturers to be comparable to the EPACT 1992 efficiencies for polyphase medium motors. It consists of the combination of efficiency level 4 for CSIR motors and efficiency level 2 for CSCR motors.

TSL 2 consists of the combination of EL 4 for CSIR motors and EL 3 for CSCR motors. This combination has the highest energy savings and net present value of any level combination utilizing CSIR EL 4.

TSL 3 consists of the combination of EL 5 for CSIR motors and EL 3 for CSCR motors. This combination has the highest energy savings and net present value of any level combination utilizing CSIR EL 5.

TSL 4 consists of the combination of EL 6 for CSIR motors and EL 4 for CSCR motors. In the "High CSCR" sensitivity case, TSL 4 has the highest energy savings of any level combination utilizing CSIR EL 6.

TSL 5 consists of the combination of EL 6 for CSIR motors and EL 3 for CSCR motors. In the Departments' reference scenarios, TSL 5 has the highest energy savings and net present value of any level combination utilizing CSIR EL 6. This combination is considered by motor manufacturers to be comparable to NEMA Premium efficiency levels for polyphase medium motors.

TSL 6 consists of the combination of EL 7 for CSIR motors and EL 8 for CSCR motors. These levels are the maximum technologically feasible levels for both motor categories.

TSL 7 consists of the combination of EL 7 for CSIR motors and EL 3 for CSCR motors. TSL 7 has the highest net present value of any level combination utilizing CSIR EL 7. Under some sensitivity scenarios, as well as the Department's reference scenario with a 3% discount rate, this level has the highest NPV of any combination of CSIR and CSCR efficiency levels.

TSL 8 consists of the combination of EL 7 for CSIR motors and EL 7 for CSCR motors. This combination exhibits the greatest energy savings of any combination of CSIR and CSCR efficiency levels.

Section 10.6.6 discusses national impact results for all possible combinations of CSIR and CSCR efficiency levels, including those not selected as TSLs.

10.6 NATIONAL ENERGY SAVINGS AND NET PRESENT VALUE RESULTS

The NIA model provides estimates of the NES and NPV for standards set at various efficiency 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 10.6.1summarizes the inputs to the NIA model.

Table 10.6.1 Inputs to the Net Present Value Calculation

Input	Data Description
Shipments	Annual shipments for each product class from shipments model. (See chapter 9.)
Effective Date of Standard	2015
Base Case Forecasted Energy Consumption	Shipment-weighted unit energy consumption (UEC), based on efficiency and hours of operation
Standards Case Energy Consumption	The UEC for each standards case, based on efficiency and hours of operation.
Annual Energy Consumption per Unit	Annual weighted-average values for each product class are a function of shipment-weighted UEC.
Total Installed Cost per Unit	Annual weighted-average values for each product class 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 chapters 7 and 8.)
Repair Cost and Maintenance Cost per Unit	Annual values are constant, and not a function of efficiency level. (See chapter 8.)
Trend in Energy Prices	Based on EIA *AEO2010* forecasts (to 2035) and extrapolation to 2065. (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 2010.

* Chapter 13 on the Utility Impact Analysis and the Environmental Assessment Report (Chapter 15) provide more detail on NEMS.

10.6.2 National Energy Savings Results

The following sections provide NES results for the standards cases analyzed for polyphase and capacitor-start motors. 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.

Table 10.6.2 and Table 10.6.3 show the NES results for the trial standard levels (TSLs) analyzed for small electric motors. For polyphase motors, the TSLs correspond to the efficiency levels analyzed in the engineering and LCC analyses. For capacitor-start motors, the TSLs consist of combinations of efficiency levels for CSIR and CSCR motors, as shown in Table 10.6.3. The capacitor-start values are presented as ranges, indicating the effects of the rate and timing of market share shifts (see section 9.4.4). The two values in the range correspond to (1) a ten-year market share shift beginning in 2015 and (2) a market share shift complete by the start of the analysis period in 2015.

Table 10.6.2 Polyphase Motors: Cumulative National Energy Savings Results

Trial standard level	National Energy Savings (quads)*		
	Not Discounted	Discounted at 3%	Discounted at 7%
1	0.05	0.03	0.01
2	0.09	0.05	0.02
3	0.17	0.09	0.04
4	0.19	0.10	0.05
4b	0.29	0.15	0.07
5	0.34	0.18	0.09
6	0.37	0.19	0.09
7	0.37	0.20	0.09

* Quadrillion British thermal units.

Table 10.6.3 Capacitor-Start Motors: Cumulative National Energy Savings Results

Trial standard level	CSIR Efficiency Level	CSCR Efficiency Level	National Energy Savings (quads)		
			Not Discounted	Discounted at 3%	Discounted at 7%
1	4	2	1.18	0.63	0.31
2	4	3	1.19	0.64	0.31
3	5	3	1.36	0.73	0.36
4	6	4	1.47	0.79	0.39
5	6	3	1.47	0.79	0.39
6	7	8	1.61	0.87	0.43
7	7	3	1.91	1.03	0.51
8	7	7	2.33	1.25	0.62

10.6.3 Annual Costs and Savings

To illustrate the basic inputs to the NPV calculations, Figure 10.6.1 presents the non-discounted annual installed cost increases and annual operating cost savings at the national level for TSL 4 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 equipment cost is the sum of the increase in the total installed cost for equipment purchased each year over the forecast period. The annual operating cost savings is the savings in operating costs for equipment 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 considered standards cases for each product class.

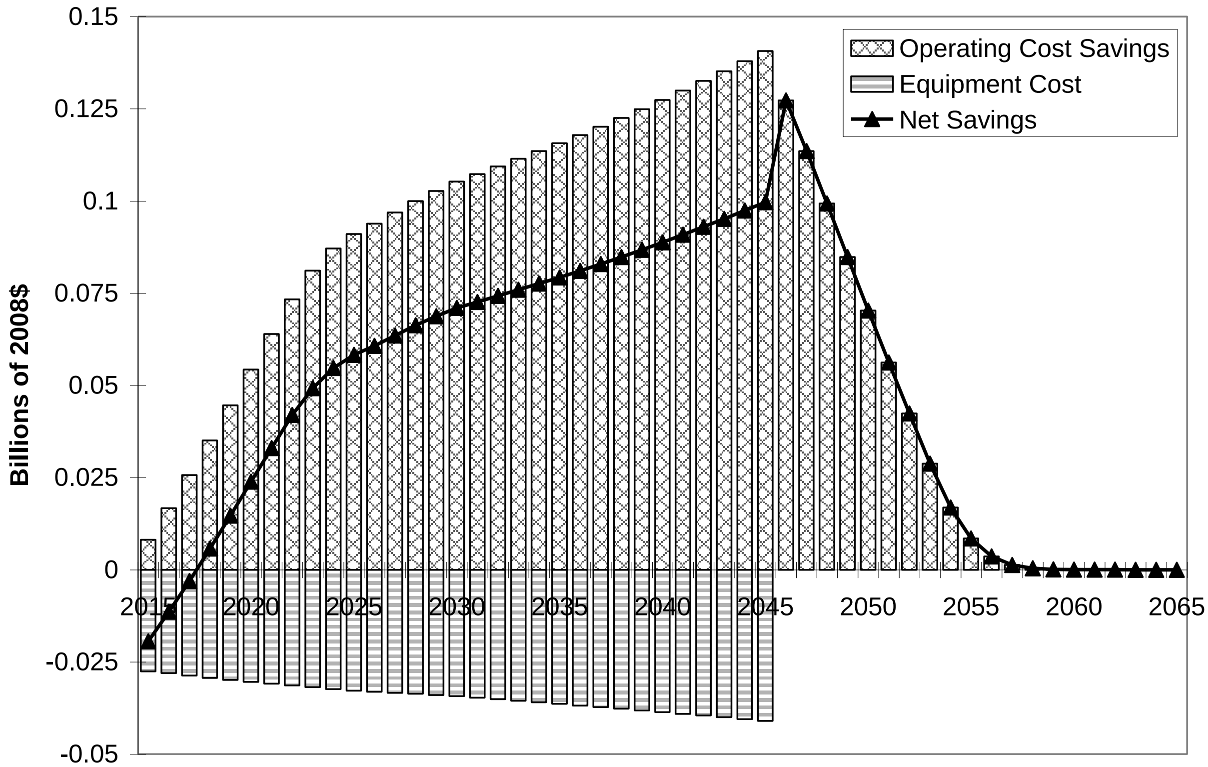

Figure 10.6.1 Non-Discounted Annual Installed Cost Increases and Annual Operating Cost Savings for Polyphase Small Electric Motors, Trial Standard Level 4

10.6.4 Net Present Value Results

The following sections provide NPV results for the TSLs analyzed for small electric motors. 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 equipment 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.

Table 10.6.4 and Table 10.6.5 show the NPV results for the trial standard levels analyzed for small electric motors. The highest TSL that has a positive NPV for both discount rates is TSL 5 for polyphase motors and TSL 8 for capacitor-start motors. The capacitor-start values are presented as ranges, indicating the effects of the rate and timing of market share shifts (see section 9.4.4).

Table 10.6.4 Polyphase Motors: Cumulative Net Present Value Results

Trial Standard Level	Net Present Value (billion 2008$)	
	7% Discount Rate	3% Discount Rate
1	0.10	0.26
2	0.22	0.55
3	0.41	1.01
4	0.42	1.05
	0.54	1.44
5	0.16	0.77
6	-0.22	0.06
7	-6.82	-12.65

Table 10.6.5 Capacitor-Start Motors: Cumulative Net Present Value Results

Trial Standard Level	CSIR Efficiency Level	CSCR Efficiency Level	Net Present Value (billion 2008$)	
			7% Discount Rate	3% Discount Rate
1	4	2	3.01	7.03
2	4	3	3.05	7.13
3	5	3	2.83	6.87
4	6	4	1.97	5.35
5	6	3	2.08	5.57
6	7	8	-9.29	-16.23
7	7	3	4.74	11.08
8	7	7	3.03	8.14

10.6.5 Sensitivity of NES and NPV to Model Inputs

The Department analyzed the effects of variation in many inputs to its NIA model. For both polyphase and capacitor-start motors, DOE analyzed four shipment growth scenarios, four electricity price forecasts, three shipment elasticity scenarios (see section 9.4.1), and three ways of accounting for reactive power charges. For capacitor-start motors, the Department also analyzed the impact of variation in the parameters of its CSIR-CSCR market share model (described in chapter 9). Appendix 10C shows the sensitivity of NES and NPV results (as well as each of their constituent parts) to these different inputs. The appendix includes capacitor-start sensitivity results with a market share transition complete by 2015. The spreadsheet tool allows the user to choose any combination of the scenarios whose results are included in the appendix, including a longer market share transition time.

Tables 10.6.6-10.6.9 show the results of the NES and NPV calculations in the Low CSCR and High CSCR alternative scenarios. The High CSCR and Low CSCR scenarios have significant differences from the reference case on the magnitude (and in some cases the sign) of the NES and NPV results. The High CSCR and Low CSCR scenarios correspond to changing the "unfamiliarity cost" associated with CSCR motors; this cost is the parameter δ in the market share model described in section 9.4.4. The Department's reference case is based on the value for this parameter which best fits the current market share of CSCR motors in different product classes, $186. The Low CSCR scenario is based on a value for this parameter which is higher by one standard deviation ($278), and the High CSCR scenario is based on a value for this parameter which is lower by one standard deviation ($94). All three scenarios use the same values for the installed costs and motor losses, but their forecasts regarding resulting customer behavior in response to standards differ. CSCR motors are commonly more efficient than CSIR motors, particularly for larger motors. The High CSCR scenario, which models a market in which more customers switch from CSIR to CSCR motors than in the reference case, has higher energy savings. The Low CSCR scenario, in contrast, shows smaller energy savings.

DOE's uncertainty in this model is the largest uncertainty in its modeling of the NES and NPV for capacitor-start motors, so the results of these alternative scenarios are presented here (Tables 10.6.6-10.6.8) to demonstrate the effect of this uncertainty on the national results of the analysis.

Table 10.6.6 Undiscounted Cumulative National Energy Savings for Capacitor-Start Small Electric Motors Under Different CSIR/CSCR Market Share Scenarios (Energy Savings between 2015 and 2045)

Trial Standard Level	National Energy Savings (quads)		
	Low CSCR Scenario	Reference Scenario	High CSCR Scenario
1	1.17	1.18	1.30
2	1.17	1.19	1.38
3	1.34	1.36	1.52
4	1.43	1.47	1.67
5	1.43	1.47	1.65
6	1.61	1.61	1.62
7	1.87	1.91	1.92
8	2.17	2.33	2.37

For many customers, particularly those using more powerful motors, CSCR motors are not only more efficient but also more cost effective. The High CSCR scenario models a market in which motor customers feel smaller barriers to switch to CSCR motors, and it has a higher NPV for each trial standard level than the reference case, whereas the Low CSCR scenario has a lower NPV.

Table 10.6.7 Capacitor-Start Motors: Cumulative Net Present Value Results in the Low CSCR Scenario

	Net Present Value (billion 2008$)	
Trial Standard Level	**7% discount rate**	**3% discount rate**
1	2.95	6.90
2	2.95	6.92
3	2.71	6.63
4	1.70	4.81
5	1.72	4.84
6	-9.30	-16.23
7	2.75	7.21
8	0.52	3.17

Table 10.6.8 Capacitor-Start Motors: Cumulative Net Present Value Results in the High CSCR Scenario

	Net Present Value (billion 2008$)	
Trial Standard Level	**7% discount rate**	**3% discount rate**
1	3.54	8.17
2	3.76	8.68
3	3.66	8.63
4	3.13	7.73
5	3.41	8.30
6	-9.29	-16.22
7	5.05	11.70
8	3.61	9.30

Electricity prices have an impact on the national net present value of an energy conservation standard. The Department considered four electricity price forecasts. Its reference scenario is based on the electricity price forecast in the Early Release case of *AEO 2010*, and it developed low- and high-energy price scenarios based on the ratio between the low- and high-energy prices presented in the AEO 2009 March Release and the reference case in that release. These alternate scenarios, as well as scenarios exploring various other sensitivities, are presented in Appendix C to this chapter.

10.6.6 Capacitor-Start National Impact Summary

DOE analyzed 8 TSLs for capacitor-start motors in detail, each made up of efficiency level requirements for both CSIR and CSCR motors. Table 10.6.10 and Table 10.6.11 show the national impacts, along with the life-cycle cost results, for each possible pair of CSIR and CSCR efficiency levels (a total of 63 combinations). For each combination, the tables show: (1) the National Energy Savings, (2) the average LCC savings for the CSIR and CSCR level, and (3) the Net Present Value of a standard at that combination of efficiency levels, at both a 3% and 7% discount rate. Table 10.6.9 acts as a key to Table 10.6.10 and Table 10.6.11. These tables are provided only for the shipments forecast scenario with a 10-year market share shift, taking place from 2015 to 2025. This table may be generated for any user-selected scenario in the national impact spreadsheet model.

Table 10.6.9 Location and Identification of Data for Each EL Combination in Tables 10.5.12 and 10.5.13

NPV at 3% Discount Rate (Billions of 2008$)	NPV at 7% Discount Rate (Billions of 2008$)	Average CSCR LCC Savings (2008$)
Average CSIR LCC Savings (2008$)		National Energy Savings (Quads)

Table 10.6.10 LCC and National Impact Summary for All Combinations of Capacitor-Start Efficiency Levels, Part One*

		CSCR														
		Baseline			EL 1			EL 2			EL 3			EL 4		
CSIR	Baseline	0.00	0.00	$0.00	0.58	0.26	$12.31	1.78	0.79	$21.07	2.57	1.13	$24.50	1.93	0.84	$10.96
		$0.00		0.00	$0.00		0.08	$0.00		0.26	$0.00		0.38	$0.00		0.32
	EL 1	1.01	0.44	$0.00	1.36	0.59	$12.31	2.35	1.03	$21.07	2.90	1.27	$24.50	2.47	1.08	$10.96
		$18.83		0.16	$18.83		0.20	$18.83		0.35	$18.83		0.43	$18.83		0.40
	EL 2	2.27	0.98	$0.00	2.41	1.04	$12.31	3.14	1.36	$21.07	3.61	1.57	$24.50	3.24	1.40	$10.96
		$31.08		0.35	$31.08		0.37	$31.08		0.48	$31.08		0.55	$31.08		0.51
	EL 3	4.10	1.79	$0.00	4.18	1.82	$12.31	4.51	1.97	$21.07	4.87	2.13	$24.50	4.56	1.99	$10.96
		$46.40		0.62	$46.40		0.63	$46.40		0.67	$46.40		0.73	$46.40		0.69
	EL 4	6.92	2.95	$0.00	6.93	2.96	$12.31	**7.03**	**3.01**	**$21.07**	**7.13**	**3.05**	**$24.50**	7.06	3.02	$10.96
		$58.27		1.16	$58.27		1.17	**$58.27**		**1.18**	**$58.27**		**1.19**	$58.27		1.19
	EL 5	6.64	2.72	$0.00	6.66	2.73	$12.31	6.77	2.78	$21.07	**6.87**	**2.83**	**$24.50**	6.79	2.79	$10.96
		$47.15		1.34	$47.15		1.34	$47.15		1.35	**$47.15**		**1.36**	$47.15		1.36
	EL 6	4.98	1.80	$0.00	5.06	1.84	$12.31	5.36	1.98	$21.07	**5.57**	**2.08**	**$24.50**	**5.35**	**1.97**	**$10.96**
		$13.43		1.42	$13.43		1.43	$13.43		1.45	**$13.43**		**1.47**	**$13.43**		**1.47**
	EL 7	6.20	2.63	$0.00	7.36	3.15	$12.31	10.02	4.29	$21.07	**11.08**	**4.74**	**$24.50**	10.57	4.45	$10.96
		($370.06)		1.11	($370.06)		1.29	($370.06)		1.73	**($370.06)**		**1.91**	($370.06)		2.05

* Levels selected by the Department as Trial Standard Levels are shown with light gray backgrounds and bold text. Negative numbers are shown in parentheses.

Table 10.6.11 LCC and National Impact Summary for All Combinations of Capacitor-Start Efficiency Levels, Part Two*

		CSCR											
		EL 5			EL 6			EL 7			EL 8		
CSIR	Baseline	1.66	0.71	($2.93)	1.05	0.43	($35.55)	1.10	0.44	($51.85)	-0.87	-0.39	($829.71)
		$0.00		0.30	$0.00		0.23	$0.00		0.25	$0.00		(0.10)
	EL 1	2.21	0.95	($2.93)	1.80	0.76	($35.55)	1.84	0.77	($51.85)	0.44	0.18	($829.71)
		$18.83		0.37	$18.83		0.33	$18.83		0.34	$18.83		0.09
	EL 2	3.11	1.34	($2.93)	2.82	1.20	($35.55)	2.86	1.22	($51.85)	1.95	0.83	($829.71)
		$31.08		0.50	$31.08		0.47	$31.08		0.48	$31.08		0.32
	EL 3	4.49	1.96	($2.93)	4.35	1.89	($35.55)	4.38	1.90	($51.85)	3.99	1.74	($829.71)
		$46.40		0.69	$46.40		0.67	$46.40		0.68	$46.40		0.61
	EL 4	7.03	3.00	($2.93)	6.97	2.98	($35.55)	6.99	2.99	($51.85)	6.89	2.94	($829.71)
		$58.27		1.18	$58.27		1.18	$58.27		1.18	$58.27		1.16
	EL 5	6.75	2.77	($2.93)	6.68	2.74	($35.55)	6.70	2.74	($51.85)	6.60	2.70	($829.71)
		$47.15		1.35	$47.15		1.35	$47.15		1.35	$47.15		1.34
	EL 6	5.22	1.90	($2.93)	4.97	1.78	($35.55)	4.98	1.78	($51.85)	4.74	1.67	($829.71)
		$13.43		1.46	$13.43		1.45	$13.43		1.45	$13.43		1.43
	EL 7	9.87	4.05	($2.93)	8.36	3.22	($35.55)	**8.14**	**3.03**	**($51.85)**	**-16.23**	**-9.29**	**($829.71)**
		($370.06)		2.10	($370.06)		2.21	**($370.06)**		**2.33**	**($370.06)**		**1.61**

* Levels selected by the Department as Trial Standard Levels are shown with light gray backgrounds and bold text. Negative numbers are shown in parentheses.

10.6.7 Annualized National Impacts

DOE calculated an annualized summary of national impacts for each trial standard level. These annualized values were calculated by determining the annual values of future equipment cost increases and operating cost savings distributed evenly among the years 2015 to 2045 (31 years total) which would have the same NPVs as the increases in costs and decrease in operating expenses caused by the trial standard levels.

Table 10.6.12 shows the annualized costs, benefits, and net benefit for each of the 7 polyphase trial standard levels. Table 10.6.13 shows the annualized national impacts for capacitor-start motors. These values are shown as a range between the lowest and highest value for each amount across three shipments scenarios: the Department's reference case with a CSIR-CSCR market share shift over the period 2015-2025, the same case with a market share shift complete by 2015, and the Department's "segmented market" case (which treats space-constrained and non-space-constrained customers separately), with shift complete by 2015.

Table 10.6.12 Annualized Costs and Benefits for Polyphase Small Electric Motors

Trial Standard Level	Ann. Equip. Cost Increase (million $2008)		Ann. Op. Cost Savings (million $2008)		Annualized Net Benefit (million $2008)	
	7% disc. rate	3% disc. rate	7% disc. rate	3% disc. rate	7% disc. rate	3% disc. rate
1	7.2	7.2	18.8	22.4	11.6	15.2
2	11.7	11.7	36.6	43.6	24.9	31.9
3	20.6	20.6	66.6	79.4	46.0	58.8
4	27.8	27.8	74.4	88.6	46.6	60.9
4b	57.0	57.0	118.0	140.5	61.0	83.5
5	122.6	122.5	140.5	167.3	18.0	44.9
6	175.1	175.0	149.9	178.5	-25.2	3.6
7	921.5	920.8	157.8	187.8	-763.7	-733.0

Table 10.6.13 Annualized Costs and Benefits for Capacitor-Start Small Electric Motors

Trial Standard Level	Ann. Equip. Cost Increase (million $2008)		Ann. Op. Cost Savings (million $2008)		Annualized Net Benefit (million $2008)	
	7% disc. rate	3% disc. rate	7% disc. rate	3% disc. rate	7% disc. rate	3% disc. rate
1	129.6	129.5	466.4	537.2	336.7	407.7
2	129.3	129.2	471.1	542.6	341.8	413.4
3	218.0	217.8	535.0	616.3	317.1	398.5
4	368.8	368.5	589.3	678.8	220.5	310.3
5	359.1	358.8	591.8	681.6	232.7	322.8
6	1688.5	1687.2	648.3	746.7	-1040.2	-940.4
7	206.9	206.7	737.1	849.1	530.3	642.4
8	533.5	533.1	872.2	1004.7	338.7	471.6

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