CHAPTER 10. NATIONAL IMPACT ANALYSIS

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CHAPTER 10. NATIONAL IMPACT ANALYSIS

10.1 INTRODUCTION

The Energy Policy and Conservation Act (EPCA) provides that any new or amended standard must be chosen so as to achieve the maximum improvement in energy efficiency that is technologically feasible, economically justified, and would save a significant amount of energy. In determining whether economic justification exists, the U.S. Department of Energy (DOE) must determine whether the benefits of an energy efficiency standard exceed its burdens. Key factors in this decision are: the total projected amount of energy savings likely to result directly from the imposition of the standard, and the savings in operating costs throughout the life of the covered equipment compared to any increase in the price of, or in the initial charges for or maintenance expenses of, the covered equipment that are likely to result from the promulgation of the standard.

To satisfy this EPCA requirement and to more fully understand the national impact of potential efficiency regulations for electric motors, DOE conducted a national impact analysis (NIA). This analysis assessed future national energy savings (NES) from electric motor energy conservation standards and the national economic impact using the net present value (NPV) metric.

This chapter describes the method used to estimate the national impacts of candidate standard levels (CSLs) for electric motors covered in this analysis. These electric motors have been categorized into three distinct equipment class groups: National Electrical Manufacturers Association (NEMA) Design A and B motors, NEMA Design C motors, and fire pump electric motors. For each of these equipment class groups, and for each equipment class, DOE evaluated the following impacts: (1) NES attributable to each potential standard level, (2) monetary value of the lifetime energy savings to consumers of the considered equipment, (3) increased total lifetime cost of the equipment because of standards, and (4) NPV resulting from energy savings (the difference between the energy cost savings and the increased total lifetime cost of the equipment).

To conduct its NIA, DOE determined both the NES and NPV for each of the efficiency levels being considered as the new standard for electric motors. DOE performed all calculations for each considered equipment class group and equipment class using Microsoft Excel spreadsheet models, which are accessible on the Internet.[a] Details and instructions for using the NIA model are provided in Appendix 10-A of the Technical Support Document (TSD). The spreadsheets combine the calculations for determining the NES and NPV for each considered equipment class group and equipment class with input from the appropriate shipments model that DOE used to project future purchases of the considered equipment. Chapter 9 provides a detailed description of the shipments models.

[a] See www.eere.energy.gov/buildings/appliance_standards/

To calculate the national impacts of new standards for all equipment class groups considered in this rulemaking DOE used scaling factors (described in Chapter 5 and section 10.3.2 below) to estimate equipment related costs and annual energy consumption for all equipment classes. DOE derived these factors from the engineering outputs for the eight representative units.

Figure 10.2.1 presents a graphical flow diagram of the electric motor NIA spreadsheet model. In the diagram, the arrows show the direction of information flow for the calculation. The information begins with inputs (shown as parallelograms). As information flows from these inputs, it is integrated into intermediate results (shown as rectangles) into major outputs (shown as boxes with curved bottom edges).

The NIA calculation started with the shipments model. This model produces a projection of annual shipments of motors. DOE used the annual projection of such shipments to produce an accounting of annual national energy savings, annual national energy cost savings, and annual national incremental non-energy costs resulting from purchasing, installing and operating the units projected to be shipped in each year of the analysis period during their estimated lifetime. The annual values, therefore, refer to the lifetime, cumulative energy related savings and non-energy related additional costs associated to the units marketed in each year of the analysis period.

To calculate the annual national energy savings, DOE first estimated the lifetime primary and fuel-fuel-cycle[b] (FFC) energy consumption at the unit level for each equipment class, and for each year in the analysis period. The unit's lifetime primary and FFC energy consumptions were then scaled up to the national level based on the annual shipments projection. The primary and FFC national energy consumptions were then evaluated, each one, for two scenarios: the *base case* scenario, with no changes in the existing energy efficiency standards; and (b) the *standards case* scenario, where energy efficiency standards are set at the energy efficiency level corresponding to one of the CSLs. This produced, for each equipment class, two sets of two streams of annual national energy consumption, from which DOE derived two streams of annual national energy savings: one that accounts for primary energy savings, and one that accounts for the FFC energy savings. The annual national primary and FFC energy savings of all equipment classes within an equipment class group were, each one, aggregated over the full analysis period into national energy primary and FFC savings by equipment class group. DOE then summed the aggregated national primary and FFC energy savings to produce the primary and FFC NESs of all equipment class groups.[c]

DOE followed a similar procedure to calculate the annual national energy cost savings and the annual national incremental non-energy costs. DOE first estimated the lifetime energy cost and the lifetime non-energy costs at unit level for each equipment class within each

[b] The full-fuel-cycle energy consumption adds to the primary energy consumption the energy consumed by the energy supply chain upstream to power plants.

[c] Because not all equipment class groups are classified into the same number of CSLs: (a) results for CSL 4 aggregates the results from Design A and B and from fire pump electric motors at CSL 4 with those estimated for Design C at CSL 3; and (b) results for CSL 5 aggregates the results from Design A and B at CSL 5 with those from fire pump electric motors at CSL 4 and Design C at CSL 3.

equipment class group, and for each year in the analysis period. The units lifetime energy and non-energy costs, for each year in the analysis period, were then scaled up to the national level based on the annual shipments projection and for the same—*base case* and *standards case*—scenarios. This produced, for each equipment class: (a) two streams of annual national energy costs, from which DOE derived a stream of annual national energy cost savings and its corresponding present-value, and (b) two streams of annual national non-energy costs, from which DOE derived a stream of annual national incremental equipment non-energy costs and its corresponding present-value. The present-values of the annual national energy cost savings and the annual national incremental non-energy costs of all equipment classes within an equipment class group were aggregated over the full analysis period, respectively, into national energy cost savings and national incremental non-energy costs by equipment class group. DOE then calculated the difference between the aggregated national energy cost savings and national incremental non-energy costs, and aggregated these values across equipment class groups to produce the NPV.[c]

Two models included in the NIA are provided below—the NES model in section 10.2, and the NPV model in section 10.3. Each technical description begins with a summary of the model. It then provides a descriptive overview of how DOE performed each model's calculations and follows with a summary of the inputs. The final subsections of each technical description describe each of the major inputs and computation steps in detail and with equations, when appropriate. After the technical model descriptions, this chapter presents the results of the NIA calculations.

10.2 NATIONAL ENERGY SAVINGS

DOE developed the NES model to estimate the total national primary and FFC energy savings using information from the life-cycle cost (LCC) relative to energy consumption, combined with the results from the shipments model. The savings shown in the NES reflect decreased energy losses resulting from the installation of more efficient electric motors nationwide, in comparison to a base case with no changes in the current national standards. Positive values of NES correspond to net energy savings, that is, a decrease in energy consumption after implementation of a standard in comparison to the energy consumption in the base case scenario.

10.2.1 National Energy Savings Overview

DOE calculated the cumulative primary and FFC energy savings from an electric motor efficiency standard, relative to a base case scenario of no standard, over the analysis period. It calculated NES for each candidate standard level, in units of quadrillion British thermal units (Btus) (quads), for standards that will be effective in the year 2015. The NES calculation started with estimates of shipments, which are outputs of the shipments model (Chapter 9). DOE then obtained estimates of electric motor parameters from the LCC analysis (Chapter 8), projections of site-to-primary conversion factors[d] from the *Annual Energy Outlook*[6] (AEO) and projections

[d] The site-to-primary factors account for electricity generation, transmission and distribution losses.

of primary-to-FFC conversion factors[e] from a NEMS-based methodology (Appendix 10-C), and calculated the market average of the total primary and FFC energy used by the units shipped in each year over their lifetime, for both a base case and a standards case. Since in the standards case part of the units shipped is more efficient than its corresponding in the base case, the average energy consumed per unit decreases in the standards case relative to the base case. For each year analyzed, the lifetime primary and FFC energy savings from all motors of a given capacity and configuration (combination of enclosure and number of poles), shipped in that year, are the differences in their primary and FFC energy use between the corresponding base case and the standards case scenarios.

[e] The primary-to-FFC factors account for the energy consumption in the supply chain of the fuels used for electricity generation.

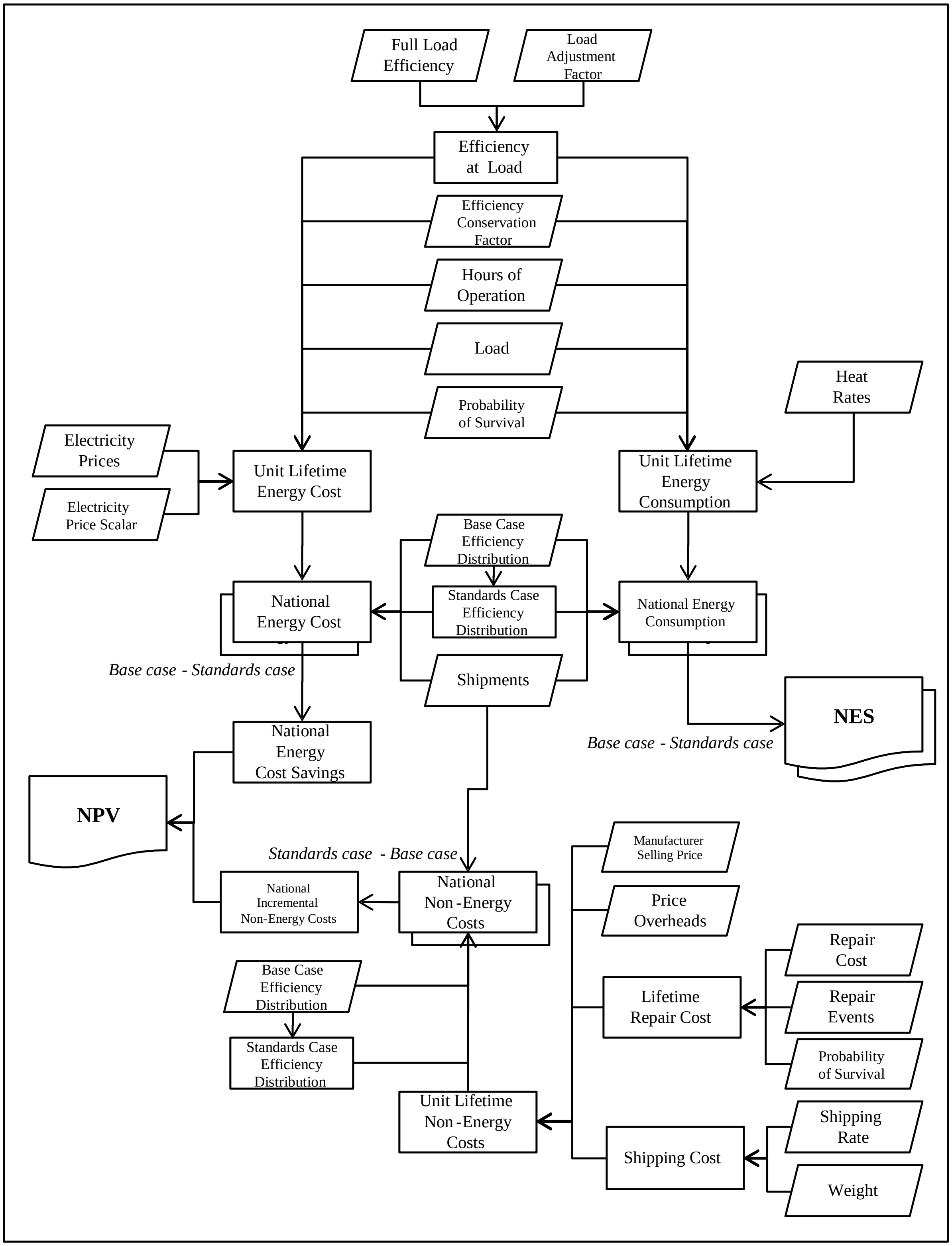

Figure 10.2.1 National Impact Analysis Model Flowchart

This calculation is expressed by the following formulas:

Lifetime Primary Energy Savings

$$nSES_{hp,g}(y) = \sum_s \sum_a \left(nSrcECbc_{hp,g}(s,a,y) - nSECst_{hp,g}(s,a,y) \right) \quad \text{Eq. 10.1}$$

$$nSECbc_{hp,g}(s,a,y) = Shp_{hp,g}(s,y) \cdot A(a) \cdot \sum_c \left(uSEC_{hp,g,c}(s,a,y) \cdot Mbc_{hp,c}(y) \right) \quad \text{Eq. 10.2}$$

$$nSECstd_{hp,g}(s,a,y) = Shp_{hp,g}(s,y) \cdot A(a) \cdot \sum_c \left(uSEC_{hp,g,c}(s,a,y) \cdot Mstd_{hp,c}(y) \right) \quad \text{Eq. 10.3}$$

$$uSEC_{hp,g,c}(s,a,y) = \sum_{i=1..LT} aSEC_{hp,g,c}(s,a,y,i) \quad \text{Eq. 10.4}$$

where:

$nSES_{hp,g}(y)$	= the lifetime primary energy savings of all motors with capacity *hp* and configuration *g* shipped in year *y*,
$nSECbc_{hp,g}(s,a,y)$	= the base case, lifetime primary energy consumption of motors with capacity *hp* and configuration *g* shipped in year *y* to be used in application *a* in sector *s*,
$nSECstd_{hp,g}(s,a,y)$	= the standards case, lifetime primary energy consumption of motors with capacity *hp* and configuration *g* shipped in year *y* to be used in application *a* in sector *s*,
$Shp_{hp,g}(s,y)$	= the number of motors with capacity *hp* and configuration *g* shipped in year *y* to sector *s*,
$A(a)$	= the probability of a motor to be used in application *a*,
$uSEC_{hp,g,c}(s,a,y)$	= the lifetime primary energy consumption of a unit with capacity *hp*, configuration *g* and efficiency level at CSL *c* shipped in year *y* to be used in application *a* in sector *s*,
$aSEC_{hp,g,c}(s,a,\mathrm{y},\mathrm{i})$	= the annual primary energy consumption in the i-th year of operation of a unit with capacity *hp*, configuration *g* and efficiency level at CSL *c*, shipped in year *y* to be used in application *a* in sector *s*,
$Mbc_{hp,c}(y)$	= the base case market share of units with capacity *hp*, configuration *g* and efficiency level at CSL *c* shipped in year *y*, and
$Mstd_{hp,c}(y)$	= the standards case market share of units with capacity *hp*, configuration *g* and efficiency level at CSL *c* shipped in year *y*.

Lifetime Full-Fuel-Cycle Energy Savings

$$nFES_{hp,g}(y) = \sum_s \sum_a \left(nFECbc_{hp,g}(s,a,y) - nFECst_{hp,g}(s,a,y) \right) \quad \text{Eq. 10.5}$$

$$nFECbc_{hp,g}(s,a,y) = Shp_{hp,g}(s,y) \cdot A(a) \cdot \sum_c \left(uFEC_{hp,g,c}(s,a,y) \cdot Mbc_{hp,c}(y) \right) \quad \text{Eq. 10.6}$$

$$nFECstd_{hp,g}(s,a,y) = Shp_{hp,g}(s,y) \cdot A(a) \cdot \sum_c \left(uFEC_{hp,g,c}(s,a,y) \cdot Mstd_{hp,c}(y)\right) \quad \text{Eq. 10.7}$$

$$uFEC_{hp,g,c}(s,a,y) = \sum_{i=1..LT} \left(aSEC_{hp,g,c}(s,a,y,i) \cdot ffc(y+i-1)\right) \quad \text{Eq. 10.8}$$

where:

$nFES_{hp,g}(y)$	= the lifetime FFC energy savings of all motors with capacity *hp* and configuration *g* shipped in year *y*,
$nFECbc_{hp,g}(s,a,y)$	= the base case, lifetime FFC energy consumption of motors with capacity *hp* and configuration *g* shipped in year *y* to be used in application *a* in sector *s*,
$nFECstd_{hp,g}(s,a,y)$	= the standards case, lifetime FFC energy consumption of motors with capacity *hp* and configuration *g* shipped in year *y* to be used in application *a* in sector *s*,
$Shp_{hp,g}(s,y)$	= the number of motors with capacity *hp* and configuration *g* shipped in year *y* to sector *s*,
$A(a)$	= the probability of a motor to be used in application *a*,
$uFEC_{hp,g,c}(s,a,y)$	= the lifetime FFC energy consumption of a unit with capacity *hp*, configuration *g* and efficiency level at CSL *c* shipped in year *y* to be used in application *a* in sector *s*,
$aSEC_{hp,g,c}(s,a,\mathrm{y},\mathrm{i})$	= the annual primary energy consumption in the i-th year of operation of a unit with capacity *hp*, configuration *g* and efficiency level at CSL *c*, shipped in year *y* to be used in application *a* in sector *s*,
$ffc(y)$	= the primary-to-FFC conversion factor in year *y*,
$Mbc_{hp,c}(y)$	= the base case market share of units with capacity *hp*, configuration *g* and efficiency level at CSL *c* shipped in year *y*, and
$Mstd_{hp,c}(y)$	= the standards case market share of units with capacity *hp*, configuration *g* and efficiency level at CSL *c* shipped in year *y*.

DOE used the lifetime primary and FFC energy savings estimated for all motors shipped from 2015 through 2044 to calculate the total primary NES (NES_{src}) and the total FFC NES (NES_{FFC}) for the analysis period. The calculation used the following formulas:

$$NES_{src} = \sum_{hp} \sum_{g} \sum_{y=2015}^{2044} nSES_{hp,g}(y) \quad \text{Eq. 10.9}$$

$$NES_{FFC} = \sum_{hp} \sum_{g} \sum_{y=2015}^{2044} nFES_{hp,g}(y) \quad \text{Eq. 10.10}$$

where:

$nSES_{hp,g}(y)$	= the lifetime primary energy savings of all motors with capacity *hp* and configuration *g* shipped in year *y*, and

$nFES_{hp,g}(y)$ = the lifetime FFC energy savings of all motors with capacity *hp* and configuration g shipped in year y.

Once the shipments model provides the estimate of shipments and the primary-to-FFC factors convert primary energy consumption into FFC energy consumption, the key to the NES calculation is in calculating the unit annual primary energy consumption and market share distributions using inputs from the LCC analysis. The next section summarizes the inputs necessary for the NES calculation and then presents them individually; the following sections detail, respectively, how the unit lifetime primary energy consumption and the standards case efficiency distribution were calculated.

10.2.2 National Energy Savings Inputs

The NES model inputs include: (a) the parameters necessary to the unit energy consumption calculation, (b) the site-to-primary conversion factors, which enable the calculation of primary energy consumption from site energy use, and (c) shipment efficiency distributions in the base case. The list of NES model inputs is as follows:

1. motor capacity;
2. annual hours of operation;
3. operating load;
4. energy efficiency (at the operating load, and including efficiency adjustment due to repairs);
5. lifetime (probability) distribution;
6. electricity site-to-primary conversion factors;
7. electricity primary-to-FFC conversion factors, and
8. base case shipments efficiency distribution.

10.2.2.1 Motor Capacity

The motor capacity refers to the unit horsepower (hp) rating converted to kilowatts (kW) using the following conversion factor: 1 hp = 0.7457 kW.

10.2.2.2 Annual Hours of Operation

For the NIA, DOE considered the average annual hours of operation by sector, application and horsepower ranges described in Chapter 7, Section 7.2.6.

10.2.2.3 Operating Load

For the NIA, DOE considered the average operating load by application described in Chapter 7, Section 7.2.5.

10.2.2.4 Energy Efficiency

For the NIA, DOE considered the energy efficiencies by CSL presented in chapter 5. Those efficiencies, however, refer to motors performance when operating at full load. Since motors usually do not operate at full load, DOE adjusted the full load efficiencies to the part-load levels corresponding to the motors' weighted average operating load across applications, based on part load efficiency data from the engineering analysis (Chapter 5). Additionally, DOE assumed that: (a) motors are repaired on average after 32,000 hours of operation[f]; (b) repair costs vary depending on motor size, configuration, and efficiency; and (c) some motors have a slight decrease in their energy efficiency after undergoing a repair. (See Chapter 8, Section 8.2.2.1 for more details.) To account for the effects of repair on the energy efficiency of motors, DOE used a time-varying adjusting factor that reduces the initial motor efficiency over its lifetime (see Table 10.2.1).[g]

Table 10.2.1 Factors to Adjust Motor Initial Efficiency to its Efficiency after Repair

Year of Operation	< 40 hp	≥ 40 hp
1-5	1.00000	1.00000
6-10	0.99333	0.99667
11-15	0.98671	0.99334
16-20	0.98013	0.99003
21-25	0.97360	0.98673
26-30	0.96711	0.98344

10.2.2.5 Lifetime Distribution

For the NIA, DOE uses motor average lifetime in years derived from motor mechanical lifetime in hours (see Chapter 8, Section 8.2.3) and from annual operating hours (see Section 10.2.2.2).

10.2.2.6 Electricity Site-to-primary Conversion Factors

The site-to-primary conversion factor for electricity is the factor by which site energy (in kilowatt-hours (kWh)) is multiplied to obtain primary (source) energy (in Btu). Since the NES estimates the change in energy use of the resource (e.g., the power plant), this conversion factor is necessary to account for losses in generation, transmission, and distribution. After calculating energy consumption at the site of its use for the base case and the standards case, DOE multiplied these values by the conversion factor to obtain the primary energy consumption in each scenario and then calculated the corresponding savings, expressed in quads. This

[f] Based on the annual operating hours by sector and application, this corresponds, on average, to a repair frequency of 5, 16, and 15 years in the industrial, commercial and agricultural sectors, respectively.

[g] Notwithstanding, DOE understands that the Electrical Apparatus Service Association (EASA) commented that a comprehensive study has been done by EASA and the Association of Electrical and Mechanical Trades to investigate the effect of repair and rewind on electric motor efficiency. EASA commented that the study showed that electric motor efficiency could be maintained by following the good practices identified in the study. (EASA, No.7 at pp. 1-2) Both EASA Standard AR100-2010 and the EASA/AEMT Rewind Study are available at http://www.easa.com/.

conversion permitted comparison across (source) fuels by taking into account the heat content of different fuels and the efficiency of different energy conversion processes. The annual conversion factor values are the U.S. averages for electricity generation for base load. DOE obtained these conversion factors using a variant of the *National Energy Modeling System* (NEMS)[7], called NEMS-BT.[h] Table 10.2.2 presents the average annual conversion factors DOE used.

10.2.2.7 Electricity Primary-to-Full-Fuel-Cycle Conversion Factors

DOE has historically presented NES in terms of primary energy savings. On August 18, 2011, DOE announced its intention to use full-fuel-cycle (FFC) measures of energy use and greenhouse gas and other emissions in the national impact analyses and emissions analyses included in future energy conservation standards rulemakings. (76 FR 51282) While DOE stated in that notice that it intended to use the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model to conduct the analysis, it also said it would review alternative methods, including the use of NEMS. After evaluating both models and the approaches discussed in the August 18, 2011 notice, DOE has determined NEMS is a more appropriate tool for this specific use. Therefore, DOE intends to use the NEMS model, rather than the GREET model, to conduct future FFC analyses.For this preliminary analysis DOE used the methodology described in Appendix 10-C to calculate the primary-to-FFC conversion factors presented in Table 10.2.2.

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[h] For more information on NEMS, refer to Energy Information Administration (EIA) at http://www.eia.gov/ . A useful summary is the "National Energy Modeling System: An Overview 2003.5" EIA approved use of the name NEMS to describe only an official version of the model without any modification to code or data. However, the analysis for electric motors entailed some minor code modifications and the model run under policy scenarios that are variations on EIA assumptions. Consequently, the abbreviation "NEMS-BT" refers to the model as used by DOE's Building Technologies (BT) Program.

Table 10.2.2 Site-to-Primary and Primary-to-Full-Fuel-Cycle Conversion Factors

Year	Conversion Factors	
	Site-to-Primary (Btu/kWh)	**Primary-to-FFC** (quad/quad)
2015	6448.1	1.05853
2016	6443.3	1.05781
2017	6432.7	1.05776
2018	6426.7	1.05747
2019	6424.7	1.05705
2020	6435.6	1.05630
2021	6467.8	1.05516
2022	6482.8	1.05493
2023	6506.5	1.05456
2024	6533.7	1.05387
2025	6533.9	1.05363
2026	6537.5	1.05344
2027	6552.1	1.05349
2028	6555.0	1.05378
2029	6551.4	1.05408
2030	6548.0	1.05452
2031	6551.8	1.05474
2032	6551.1	1.05482
2033	6548.5	1.05498
2034	6550.0	1.05528
2035	6561.1	1.05535
2036-2044	6561.1	1.05535

10.2.2.8 Base Case Shipment Efficiency Distribution

To estimate market averages for unit energy consumption, DOE used statistical distributions of shipments across CSLs. For the base case, DOE developed such distributions from a database which DOE built upon data collected from internet catalogs from six major manufacturers and one large distributor (see Table 10.2.4), and considered those distributions to remain constant over the analysis period.

Table 10.2.3 Base Case Energy Efficiency Distributions

	Market Share in 2015					
	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4	CSL 5
NEMA Design A and B Electric Motors						
1-5 hp	5.5%	38.4%	44.4%	7.6%	3.0%	1.1%
6-20 hp	4.7%	35.3%	44.3%	8.7%	6.1%	0.8%
21-50 hp	5.3%	30.3%	47.8%	8.8%	7.9%	0.0%
51-100 hp	5.4%	28.6%	48.4%	10.1%	5.0%	2.5%
101-200 hp	5.4%	23.3%	53.9%	12.0%	4.8%	0.6%
201-500 hp	11.2%	49.9%	32.0%	5.9%	0.9%	0.0%
NEMA Design C Electric Motors						
1-5 hp	92.3%	7.7%	0.0%	0.0%	-	-
6-20 hp	100.0%	0.0%	0.0%	0.0%	-	-
21-50 hp	73.3%	26.7%	0.0%	0.0%	-	-
51-100 hp	50.0%	50.0%	0.0%	0.0%	-	-
101-200 hp	47.8%	30.4%	21.7%	0.0%	-	-
Fire Pump Electric Motors						
1-5 hp	94.9%	5.1%	0.0%	0.0%	0.0%	-
6-20 hp	100.0%	0.0%	0.0%	0.0%	0.0%	-
21-50 hp	81.7%	5.5%	12.8%	0.0%	0.0%	-
51-100 hp	80.6%	2.0%	17.3%	0.0%	0.0%	-
101-200 hp	73.5%	17.6%	8.8%	0.0%	0.0%	-
201-500 hp	75.0%	25.0%	0.0%	0.0%	0.0%	-

10.2.3 Unit Annual Primary Energy Consumption

The unit annual primary energy consumption expresses an estimate of the amount of primary energy that a motor of a given equipment class, meeting the efficiency level of a given CSL, and shipped in a given year to a given sector to be used in a given application will consume in each year of its lifetime. It refers to the variable $aSEC_{hp,g,c}$ in Eq. 10.4 and Eq. 10.8, and is evaluated from the following formulas:

$$aSEC_{hp,g,c}(s,a,y,i) = UEC_{hp,g,c}(s,a,i) \cdot O_{hp}(s,i) \cdot StoS(y+i-1) \qquad \text{Eq. 10.11}$$

$$UEC_{hp,g,c}(s,a,i) = \frac{(hp \times 0.757) \cdot Load(a) \cdot Hours_{hp}(s,a)}{fEff_c \cdot aEff_{hp,c}(a) \cdot Conserv(i)} \qquad \text{Eq. 10.12}$$

where:

$aSEC_{hp,g,c}(s,a,y,i)$ = the annual primary energy consumption in the i-th year of operation of a unit with capacity *hp*, configuration *g* and efficiency level at CSL *c* shipped in year *y* to be used in application *a* in sector *s*,

$UEC_{hp,g,c}(s,a,i)$ = the annual site energy consumption in the *i*-th year of operation of a unit with capacity *hp*, configuration *g* and efficiency level at CSL *c* used for application *a* in sector *s*,

$StoS(t)$ = the site-to-primary conversion factor projected to year *t*,
$O_{hp}(s,i)$ = the probability that a unit with capacity *hp*, used in sector *s* will be in operation in the *i*-th year of its lifetime,
hp = the unit capacity (in horse-power),
$Load(a)$ = the typical load of a motor used in application *a*,
$Hours_{hp}(s,a)$ = annual hours of operation of a unit with capacity *hp*, used for application *a* in sector *s*,
$fEff_c$ = the full-load efficiency of a unit with efficiency level at CSL *c*,
$aEff_{hp,c}(a)$ = the factor used to adjust the full-load efficiency of a unit with capacity *hp* and efficiency level at CSL *c* used in application *a* to the efficiency corresponding to its typical load, and
$Conserv(i)$ = the energy efficiency conservation factor used to reduce the unit initial efficiency to the efficiency it is estimated to present in its *i*-th year of operation due to repairs.

10.2.4 Standards Case Shipment Efficiency Distribution

Section 10.2.2.8 described the market efficiency distribution across CSLs that DOE used for the base case scenario. For the standards case, DOE relied on the base case distribution and calculated the efficiency distributions from the following expression (roll-up scenario approach):

$$Mstd_{hp,c} = \begin{cases} 0, & c < c^* \\ \sum_{j=1}^{c^*} Mbc_{hp,j}, & c = c^* \\ Mbc_{hp,c}, & c > c^* \end{cases} \qquad \text{Eq. 10.13}$$

where:

$Mstd_{hp,c}(y)$ = the standards case market share of units with capacity *hp* and efficiency level at CSL *c* shipped in year *y*,
$Mbc_{hp,c}(y)$ = the base case market share of units with capacity *hp* and efficiency level at CSL *c* shipped in year *y*, and
c^* = the selected CSL.

10.3 NET PRESENT VALUE

DOE estimated the national financial impact on consumers from the imposition of new energy efficiency standards using a national NPV accounting component in the national impact spreadsheet. DOE combined the output of the shipments model with energy and financial data from the LCC analysis to calculate an annual stream of costs and benefits resulting from candidate electric motors energy efficiency standards. It discounted this time series to the year 2012 and summed the result, yielding the national NPV.

10.3.1 Net Present Value Overview

The NPV is the present value of the incremental economic impact of a candidate standard level. Like the NES, the NPV calculation started with motor shipments, estimates of which are outputs from the shipments model. DOE then obtained motor input data and average electricity costs from the LCC analysis, and estimated motor non-energy and energy lifetime costs. For both a base case and a standards case, DOE first calculated the amount spent on motor purchases and lifetime repairs,[i] and then calculated the lifetime energy cost by applying the average electricity prices to the electricity used by motors shipped at each year of the analysis period over their lifetime. In the standards case, more expensive yet more efficient units replace the less efficient ones. Thus, in the standards case, the market average lifetime energy cost per unit is lower relative to the base case, while the lifetime equipment non-energy costs are greater. When the energy cost decrease outweighs the non-energy costs increase, the standards have a positive impact on consumers; otherwise, the standards impact is negative.

DOE discounted the non-energy and energy expenses with motors using a national average discount factor. The discount factor converts a future expense to a present value. The difference in present value of the non-energy and energy expenses between the base case and the standards case scenarios leads to the national NPV impact. DOE calculated the NPV impact in 2012 from motors that were purchased between the effective date of the standard and 2044, inclusive, to calculate the total NPV impact from purchases during the analysis period. Mathematically, the NPV is the value in the present time of a time series of costs and savings, described by the equation:

$$NPV = PVS - PVC \qquad \text{Eq. 10.14}$$

where:

PVS = the present value of electricity cost savings, and
PVC = the present value of incremental non-energy costs.

PVS and PVC are determined according to the following expressions:

$$PVS = \sum_{hp}\sum_{g}\sum_{y=2015}^{2044} nECS_{hp,g}(y)\cdot(1+r)^{2012-y} \qquad \text{Eq. 10.15}$$

$$nECS_{hp,g}(y) = \sum_s\sum_a\left(nNCbc_{hp,g}(s,a,y) - nNCst_{hp,g}(s,a,y)\right) \qquad \text{Eq. 10.16}$$

$$nNCbc_{hp,g}(s,a,y) = Shp_{hp,g}(s,y)\cdot A(a)\cdot\sum_c\left(uNC_{hp,g,c}(s,a,y)\cdot Mbc_{hp,c}(y)\right) \qquad \text{Eq. 10.17}$$

[i] DOE did not account for installation costs and maintenance costs. Although these costs might have significant impacts on a user's budget, they do not vary with the efficiency level of the motor and therefore would have no impact in the difference of non-energy costs between the base case and the standards case scenarios.

$$nNCst_{hp,g}(s,a,y) = Shp_{hp,g}(s,y) \cdot A(a) \cdot \sum_c \left(uNC_{hp,g,c}(s,a,y) \cdot Mst_{hp,c}(y) \right) \qquad \text{Eq. 10.18}$$

and:

$$PVS = \sum_{hp} \sum_{g} \sum_{y=2015}^{2044} nIEC_{hp,g}(y) \times (1+r)^{2012-y} \qquad \text{Eq. 10.19}$$

$$nIEC_{hp,g}(y) = \sum_s \sum_a \left(nQCbc_{hp,g}(s,a,y) - nQCst_{hp,g}(s,a,y) \right) \qquad \text{Eq. 10.20}$$

$$nQCbc_{hp,g}(s,a,y) = Shp_{hp,g}(s,y) \cdot A(a) \cdot \sum_c \left(uQC_{hp,g,c}(s,a,y) \cdot Mbc_{hp,c}(y) \right) \qquad \text{Eq. 10.21}$$

$$nQCst_{hp,g}(s,a,y) = Shp_{hp,g}(s,y) \cdot A(a) \cdot \sum_c \left(uQC_{hp,g,c}(s,a,y) \cdot Mst_{hp,c}(y) \right) \qquad \text{Eq. 10.22}$$

where:

$nECS_{hp,g}(y)$	= the lifetime energy cost savings of all motors shipped in year *y*,
$nNCbc_{hp,g}(s,a,y)$	= the base case, lifetime energy cost of all motors shipped in year *y*,
$nNCst_{hp,g}(s,a,y)$	= the standards case, lifetime energy cost of all motors shipped in year *y*,
$uNC_{hp,g,c}(s,a,y)$	= the lifetime energy cost of a unit with efficiency level at CSL *c* shipped in year *y*,
$nIECS_{hp,g}(y)$	= the lifetime incremental equipment non-energy costs of all motors shipped in year *y*,
$nQCbc_{hp,g}(s,a,y)$	= the base case, lifetime equipment non-energy costs of all motors shipped in year *y*,
$nQCst_{hp,g}(s,a,y)$	= the standards case, lifetime equipment non-energy costs of all motors shipped in year *y*,
$uQC_{hp,g,c}(s,a,y)$	= the lifetime equipment non-energy costs of a unit with efficiency level at CSL *c* shipped in year *y*,
$Shp_{hp,g}(s,y)$	= the number of motors with capacity *hp* and configuration *g* shipped in year *y* to sector *s*,
$Mbc_{hp,c}(y)$	= the base case market share of units with capacity *hp*, configuration *g* and efficiency level at CSL *c* shipped in year *y*, and
$Mst_{hp,c}(y)$	= the standards case market share of units with capacity *hp*, configuration *g* and efficiency level at CSL *c* shipped in year *y*, and
r	= the discount rate.

Once the shipments model provides the estimate of shipments, the following sections describe the inputs necessary for the NPV calculation and detail how unit lifetime energy and non-energy costs are calculated.

10.3.2 Net Present Value Inputs

The NPV model inputs include: (a) the parameters that help calculate the unit energy consumption, (b) the electricity prices that enable the calculation of energy costs, (c) equipment first- and non-energy operating costs, and (d) shipment efficiency distributions for the base case. The list of NPV model inputs is as follows:

1. motor capacity;
2. annual hours of operation;
3. operating load;
4. energy efficiency (at the operating load, and including efficiency degradation due to repairs);
5. manufacturer selling price (MSP) and price overheads;
6. motor weight and shipment costs;
7. repair costs;
8. lifetime (probability) distribution;
9. electricity price;
10. discount rate;
11. base case shipments efficiency distribution.

Inputs 1-4, 8 and 11 have already been introduced in Section 10.2.2 and therefore are not described in this section.

10.3.2.1 Manufacturer Selling Price and Price Overheads

The Engineering Analysis, chapter 5 provides MSP data for eight representative units. DOE developed scaling relationships to estimate MSP for all covered equipment classes.

For each CSL, DOE first established an index to describe how MSP varies by pole and enclosure across horsepower ratings. DOE established these indices using statistical estimates derived from a database of motor prices which DOE built upon data collected from internet catalogs from six major manufacturers and one large distributor (see Table 10.3.1 for an example of these indices estimated for Designs A and B motors, CSL 1.).

Table 10.3.1 Example of Manufacturer Selling Price Scaling Index Across Poles and Enclosures (Designs A and B motors, CSL 1)

	Enclosed				Open			
hp	**2 poles**	**4 poles**	**6 poles**	**8 poles**	**2 poles**	**4 poles**	**6 poles**	**8 poles**
1	0.9729	1.0000	1.0271	1.0543	0.9215	0.9487	0.9758	1.0030
1.5	0.9623	1.0000	1.0377	1.0753	0.8911	0.9288	0.9665	1.0041
2	0.9533	1.0000	1.0467	1.0934	0.8650	0.9117	0.9584	1.0051
3	0.9385	1.0000	1.0615	1.1230	0.8222	0.8837	0.9452	1.0067
5	0.9177	1.0000	1.0823	1.1647	0.7620	0.8443	0.9266	1.0090
7.5	0.9009	1.0000	1.0991	1.1983	0.7134	0.8125	0.9117	1.0108
10	0.8896	1.0000	1.1104	1.2208	0.6809	0.7912	0.9016	1.0120
15	0.8755	1.0000	1.1245	1.2491	0.6399	0.7645	0.8890	1.0136
20	0.8669	1.0000	1.1331	1.2662	0.6153	0.7484	0.8814	1.0145
25	0.8612	1.0000	1.1388	1.2776	0.5988	0.7376	0.8764	1.0151
30	0.8571	1.0000	1.1429	1.2857	0.5870	0.7299	0.8727	1.0156
40	0.8517	1.0000	1.1483	1.2966	0.5712	0.7196	0.8679	1.0162
50	0.8482	1.0000	1.1518	1.3036	0.5612	0.7130	0.8648	1.0166
60	0.8458	1.0000	1.1542	1.3084	0.5542	0.7084	0.8626	1.0168
75	0.8433	1.0000	1.1567	1.3134	0.5470	0.7037	0.8604	1.0171
100	0.8407	1.0000	1.1593	1.3185	0.5396	0.6989	0.8581	1.0174
125	0.8392	1.0000	1.1608	1.3217	0.5350	0.6959	0.8567	1.0175
150	0.8381	1.0000	1.1619	1.3238	0.5319	0.6939	0.8558	1.0177
200	0.8367	1.0000	1.1633	1.3265	0.5280	0.6913	0.8545	1.0178
250	0.8359	1.0000	1.1641	1.3282	0.5256	0.6897	0.8538	1.0179
300	0.8354	1.0000	1.1646	1.3293	0.5240	0.6887	0.8533	1.0180
350	0.8350	1.0000	1.1650	1.3301	0.5229	0.6879	0.8530	1.0180
400	0.8347	1.0000	1.1653	1.3307	0.5220	0.6873	0.8527	1.0180
450	0.8344	1.0000	1.1656	1.3312	0.5213	0.6869	0.8525	1.0181
500	0.8342	1.0000	1.1658	1.3315	0.5208	0.6865	0.8523	1.0181

For each equipment class group and CSL level, using the MSP from the engineering analysis, DOE developed an equation to scale the MSP of a 4-pole enclosed motor across motor horsepower. The relations derived from power law regressions, with $0.981 < R^2 < 0.999$, are expressed by the following equation:

$$MSP_{4,e}(hp) = a.(hp)^b \qquad \text{Eq. 10.23}$$

where:

$MSP_{4,e}(hp)$	= the MSP of a 4-pole enclosed unit with capacity *hp*, and
a and b	= parameters calibrated by equipment class group and CSL.

Table 10.3.2 provides *a* and *b* values for all CSLs by equipment class group. As mentioned in Chapter 5, the MSPs of fire pump electric motors are the same as the ones used for NEMA Designs A and B motors.

Table 10.3.2 Manufacturer Selling Price Scaling Equation Parameters across Horsepower

NEMA Design A and B motors, and fire pump electric motors						
	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4	CSL 5
a	1.133E+02	1.110E+02	1.237E+02	1.256E+02	1.806E+02	2.001E+02
b	6.241E-01	6.657E-01	6.702E-01	6.853E-01	6.826E-01	6.825E-01
NEMA Design C motors						
	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4	CSL 5
a	1.133E+02	1.20E+02	1.98E+02	2.11E+02	-	-
b	6.52E-01	6.70E-01	5.93E-01	5.97E-01	-	-

Figure 10.3.1 shows an example of the scaling relations across horsepower for NEMA Designs A and B motors and fire pump electric motors.

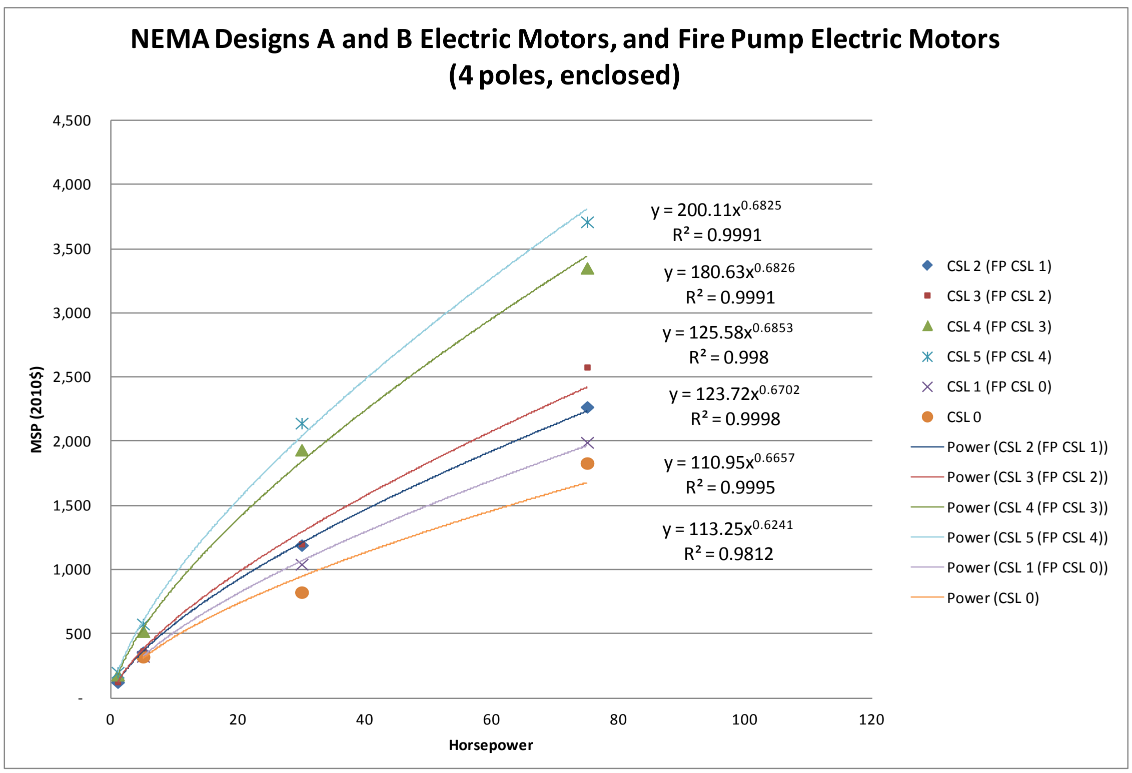

Figure 10.3.1 Example of Manufacturer Selling Price Scaling Equation across Horsepower

Using the scaling relations across horsepower, DOE estimated the MSP for 4 poles enclosed motors at each CSL, for each equipment class group and all horsepower ratings. DOE then used the index presented in Table 10.3.1 to obtain MSP estimates for all equipment classes. The final MSP estimates are available in the NIA spreadsheet.

In the NIA, an average baseline and incremental markup are applied to derive equipment prices from the MSPs. Chapter 6 provides more details on the markups calculation.

10.3.2.2 Projection of Future Equipment Prices

For reasons discussed in chapter 8 of the TSD (section 8.2.1.1), DOE used a constant price assumption for the default projection in the NIA. To investigate the impact of different equipment price projections on the consumer net present value (NPV) for the considered CSLs for electric motors, DOE also considered two alternative price trends. One of these used an exponential fit on the deflated price index for electric motors, and the other is based on *AEO2011*'s projected price index for industrial equipment. Details on how these alternative price trends were developed are in Appendix 10-B, which also presents the results of the sensitivity analysis.

10.3.2.3 Motor Weight and Shipment Costs

DOE used the same methodology described in section 10.3.2.1 to derive weight data for all covered equipment classes based on outputs from the engineering analysis, chapter 5.

For each CSL, DOE established an index to describe how motor weight varies by pole and enclosure across horsepower ratings. DOE established these indices using statistical estimates derived from a database of motor weights which DOE built upon data collected from internet catalogs from six major manufacturers and one large distributor (see Table 10.3.3 for an example of these indices estimated for Designs A and B motors, CSL 1.).

Table 10.3.3 Example of Weight Scaling Index Across Poles and Enclosures (Designs A and B motors, CSL 1)

	Enclosed				Open			
hp	**2 poles**	**4 poles**	**6 poles**	**8 poles**	**2 poles**	**4 poles**	**6 poles**	**8 poles**
1	0.977	1.000	1.023	1.045	0.936	0.958	0.981	1.003
1.5	0.968	1.000	1.032	1.063	0.910	0.941	0.973	1.005
2	0.960	1.000	1.040	1.080	0.887	0.926	0.966	1.006
3	0.947	1.000	1.053	1.107	0.848	0.901	0.955	1.008
5	0.926	1.000	1.074	1.148	0.790	0.864	0.938	1.011
7.5	0.909	1.000	1.091	1.182	0.741	0.832	0.923	1.014
10	0.897	1.000	1.103	1.206	0.707	0.810	0.913	1.016
15	0.881	1.000	1.119	1.238	0.662	0.781	0.899	1.018
20	0.871	1.000	1.129	1.257	0.634	0.762	0.891	1.020
25	0.865	1.000	1.135	1.271	0.615	0.750	0.885	1.021
30	0.860	1.000	1.140	1.280	0.601	0.741	0.881	1.021
40	0.853	1.000	1.147	1.294	0.582	0.729	0.876	1.022
50	0.849	1.000	1.151	1.302	0.570	0.721	0.872	1.023
60	0.846	1.000	1.154	1.308	0.561	0.715	0.869	1.024
75	0.843	1.000	1.157	1.314	0.552	0.710	0.867	1.024
100	0.840	1.000	1.160	1.321	0.543	0.704	0.864	1.025
125	0.838	1.000	1.162	1.325	0.537	0.700	0.862	1.025
150	0.836	1.000	1.164	1.328	0.534	0.697	0.861	1.025
200	0.834	1.000	1.166	1.331	0.529	0.694	0.860	1.025
250	0.833	1.000	1.167	1.333	0.526	0.692	0.859	1.025
300	0.833	1.000	1.167	1.335	0.524	0.691	0.858	1.026
350	0.832	1.000	1.168	1.336	0.522	0.690	0.858	1.026
400	0.832	1.000	1.168	1.337	0.521	0.689	0.857	1.026
450	0.831	1.000	1.169	1.337	0.520	0.689	0.857	1.026
500	0.831	1.000	1.169	1.338	0.519	0.688	0.857	1.026

For each CSL level and equipment class group, using the weight data from the engineering analysis, DOE developed an equation to scale the weight of a 4-pole enclosed motor by horsepower. The relationships, derived from power law regressions ($0.992< R^2< 0.999$), are expressed by the following equations:

$$Weight_{4,e}(hp) = a'.(hp)^{b'} \quad \text{Eq. 10.24}$$

where:

$Weight_{4,e}(hp)$	= the weight of a 4-pole enclosed unit with capacity *hp*, and
a' and b'	= parameters calibrated by equipment class group and CSL.

Table 10.3.4 below provides *a'* and *b'* values for all CSLs by equipment class group. As mentioned in Chapter 5, the weights of fire pump electric motors are the same as the ones used for NEMA Designs A and B motors.

Table 10.3.4 Weight Scaling Equation Parameters across Horsepower

NEMA Designs A and B motors, and Fire Pump Electric Motors						
	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4	CSL 5
a'	2.285E+01	2.215E+01	2.878E+01	2.720E+01	3.352E+01	3.520E+01
b'	7.837E-01	8.441E-01	8.144E-01	8.298E-01	8.230E-01	8.289E-01
NEMA Design C electric motors						
	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4	CSL 5
a'	2.285E+01	2.55E+01	3.26E+01	3.37E+01	-	-
b'	8.241E-01	8.40E-01	7.86E-01	7.86E-01	-	-

Using the scaling relations across horsepower, DOE estimated the weight for 4-pole enclosed motors at each CSL, for each equipment class group and all horsepower ratings. DOE then used the index presented in Table 10.3.3 to obtain weight estimates for all equipment classes. The final weight estimates are available in the NIA spreadsheet.

10.3.2.4 Repair Costs

DOE calculated the repair costs in two steps. First DOE considered the cost of one repair event by motor horsepower, configuration and efficiency level described in chapter 8, section 8.2.2.4. Then DOE calculated the lifetime repair cost of a motor with a given horsepower, configuration and efficiency level, operating in a certain sector, as the present-value of a stream of repair events occurring every 5, 15 or 16 years (depending on the sector) after the motor's warranty period and during 30 years. For the calculation of the present-value DOE used the two discount rates discussed in section 10.3.2.6. However, DOE understands that not all motors will operate for 30 years. Consequently, in the calculation of present value, DOE multiplied the cost of each repair event by the probability that the motor will be in operation by that time, according to its horsepower rating and the sector where the motor is used. (See section 10.2.2.5 above for more about lifetime distributions.)

10.3.2.5 Electricity Prices

For the NIA, DOE considered the electricity prices by sector as national weighted averages of the regional electricity prices described in Chapter 8 of the TSD, section 8.2.2.2.

10.3.2.6 Discount Rate

The discount rate expresses the time value of money. DOE used real discount rates of 3 percent and 7 percent, as established by the U.S. Office of Management and Budget (OMB) guidelines on regulatory analysis.[8] The discount rates DOE used in the LCC are distinct from those it used in the NPV calculations, in that the NPV discount rates represent the societal rate of return on capital investment, whereas LCC discount rates reflect the owner cost of capital and the financial environment of electric utilities and commercial and industrial entities.

10.3.3 Unit Lifetime Energy Cost

The unit lifetime energy cost expresses an estimate of the market average expense with electricity that owners of all motors of a given equipment class, shipped in a given year, will have to operate these motors over their lifetime. It refers to the variable $uLTNC_{hp,g,c}$ in Eq. 10.17 and Eq. 10.18, and is evaluated as the sum of the annual energy cost over the motor lifetime:

$$uLTNC_{hp,g,c}(s,a,y) = \sum_{i=1}^{30}\left(UEC_{hp,g,c}(s,a,i) \cdot nP(y+i-1) \cdot (1+r)^{1-i} \cdot O_{hp}(s,i)\right) \quad \text{Eq. 10.25}$$

$$UEC_{hp,g,c}(s,a,i) = \frac{(hp \times 0.757) \cdot Load(a) \cdot Hours_{hp}(s,a)}{fEff_c \cdot aEff_{hp,c}(a) \cdot Conserv(i)} \quad \text{Eq. 10.26}$$

where:

$uLTNC_{\mathrm{hp,g,}c}(s,a,y)$	= the lifetime energy cost of a unit with capacity *hp*, configuration *g* and efficiency level at CSL *c*, shipped in year *y* and used for application *a* in sector *s*,
$UEC_{\mathrm{hp,g,}c}(s,a,i)$	= the site energy consumption in the *i*-th year of operation of a unit with capacity *hp*, configuration *g* and efficiency level at CSL *c* used for application *a* in sector *s*,
$nP(\mathrm{t})$	= the national average electricity price in year *t*,
r	= the discount rate,
$O_{hp}(s,i)$	= the probability that a unit with capacity *hp*, used in sector *s* will be in operation in the *i*-th year of its lifetime,
hp	= the unit capacity (in horse-power),
$Load(a)$	= the typical load of a motor used in application *a*,
$Hours_{hp}(s,a)$	= annual hours of operation of a unit with capacity *hp*, used for application *a* in sector *s*,
$fEff_c$	= the full-load efficiency of a unit with efficiency level at CSL *c*,
$aEff_{hp,c}(a)$	= the factor used to adjust the full-load efficiency of a unit with capacity *hp* and efficiency level at CSL *c* used in application *a* to the efficiency corresponding to its typical load, and
$Conserv(i)$	= the energy efficiency conservation factor used to reduce the unit initial efficiency to the efficiency it is estimated to present in its *i*-th year of operation due to repairs.

10.3.4 Unit Lifetime Non-Energy Costs

The unit lifetime non-energy costs expresses an estimate of the market average expenses that owners of all motors of a given equipment class, shipped in a given year, will have with purchasing and repairing these motors over their lifetime. It refers to the variable $uLTQC_{hp,g,c}$ in Eq. 10.21 and Eq. 10.22, and is evaluated as the sum of the motor initial costs with the sum of all repair costs over the motor lifetime:

$$uLTQC_{hp,g,c}(s,y) = uIC_{hp,g,c}(y) + \sum_{i=1}^{30}\left(uRC_{hp,g,c}(i) \cdot (1+r)^{1-i} \cdot O_{hp}(s,i)\right) \quad \text{Eq. 10.27}$$

$$uIC_{hp,g,c}(y) = kP(y) \cdot uQC_{hp,g,c} + uSC_{hp,g,c} \quad \text{Eq. 10.28}$$

$$uQC_{hp,g,c} = MSP_{hp,g,0} \cdot (OVHbase - OVHinc) + MSP_{hp,g,c} \cdot OVHinc \quad \text{Eq. 10.29}$$

$$uSC_{hp,g,c} = uWeight_{hp,g,c} \cdot sP \quad \text{Eq. 10.30}$$

$$uRC_{hp,g,c}(i) = \begin{cases} uRCepact_{hp,g} \cdot kR_c, i = 6, 11, 16, 21, 26 \\ 0, i \neq 6, 11, 16, 21, 26 \end{cases} \quad \text{Eq. 10.31}$$

where:

$uLTQC_{\mathrm{hp,g},c}(s,a,y)$	= the lifetime non-energy costs of a unit with capacity *hp*, configuration *g* and efficiency level at CSL *c*, shipped in year *y* to sector *s*,
$uIC_{\mathrm{hp,g},c}(y)$	= the total installed cost of a unit with capacity *hp*, configuration *g* and efficiency level at CSL *c*, shipped in year *y*,
$\mathrm{kP(y)}$	= the price-trend multiplier for a unit shipped in year *y*,
$uQC_{\mathrm{hp,g},c}$	= the retail price of a unit with capacity *hp*, configuration *g* and efficiency level at CSL *c*,
$uSC_{\mathrm{hp,g},c}$	= the shipment cost of a unit with capacity *hp*, configuration *g* and efficiency level at CSL *c*,
$MSP_{\mathrm{hp,g},c}$	= the manufacturer price of a unit with capacity *hp*, configuration *g* and efficiency level at CSL *c*,
$\mathrm{OVHbase}$	= the baseline price overhead,
OVHinc	= the incremental price overhead,
$uWeight_{\mathrm{hp,g},c}$	= the weight of a unit with capacity *hp*, configuration *g* and efficiency level at CSL *c*,
sP	= the per pound shipment cost,
$uRC_{\mathrm{hp,g},c}(i)$	= the repair cost of a unit with capacity *hp*, configuration *g* and efficiency level at CSL *c* in its *i*-th year of operation,
$\mathrm{uRCepact}_{\mathrm{hp,g}}$	= the repair cost of a unit with capacity *hp*, configuration *g* and efficiency level below the applicable under the Energy Policy Act of 1992 (EPACT 1992),
kR_c	= the repair cost adder of a unit with efficiency level at CSL *c* relative to the repair cost of a unit with efficiency level below EPACT 1992,
$\mathrm{O}_{\mathrm{hp}}(s,i)$	= the probability that a unit with capacity *hp*, used in sector *s* will be in operation in the *i*-th year of its lifetime, and
r	= the discount rate.

10.4 RESULTS

10.4.1 National Energy Savings and Net Present Value for Candidate Standard Levels

DOE evaluated the NES and NPV using the inputs and methodologies described in sections 10.2 and 10.3 for each CSL within each equipment class group. Table 10.4.1 to Table 10.4.6 present NES and NPV results for each equipment class group, disaggregated by sector and motor horsepower ranges. Table 10.4.7 and Table 10.4.8 summarize the NES and NPV results for all equipment class groups.

Table 10.4.1 National Energy Savings for NEMA Designs A and B Motors (trillion Btu)

Primary	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**	**CSL 5**
Industry					
1-5 hp	139.8	494.5	782.4	1100.8	1400.3
6-20 hp	106.9	455.1	743.9	1072.7	1202.6
21-50 hp	66.6	275.9	486.8	703.7	703.7
51-100 hp	83.4	405.4	721.5	1060.6	1377.4
101-200 hp	64.2	339.2	688.1	1046.7	1390.5
201-500 hp	53.6	489.4	828.4	1147.9	1466.1
Commercial					
1-5 hp	129.9	459.4	726.8	1022.6	1300.9
6-20 hp	177.6	756.0	1236.0	1782.3	1998.1
21-50 hp	94.8	392.4	692.3	1000.7	1000.7
51-100 hp	20.3	98.5	175.3	257.6	334.6
101-200 hp	11.8	62.6	126.9	193.1	256.5
201-500 hp	15.5	141.8	239.9	332.5	424.7
Agriculture					
1-5 hp	0.0	0.0	0.0	0.0	0.0
6-20 hp	0.0	0.0	0.0	0.0	0.0
21-50 hp	0.0	0.0	0.0	0.0	0.0
51-100 hp	4.7	22.8	40.5	59.6	77.3
101-200 hp	1.5	8.1	16.3	24.8	33.0
201-500 hp	1.4	12.9	21.8	30.1	38.5
Full-Fuel Cycle	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**	**CSL 5**
Industry					
1-5 hp	147.5	521.8	825.5	1161.4	1477.5
6-20 hp	112.8	480.1	784.9	1131.8	1268.9
21-50 hp	70.3	291.2	513.7	742.4	742.4
51-100 hp	88.0	427.7	761.3	1119.0	1453.3
101-200 hp	67.8	357.9	726.1	1104.4	1467.1
201-500 hp	56.6	516.4	874.1	1211.2	1547.0

Commercial					
1-5 hp	137.0	484.7	766.9	1078.9	1372.6
6-20 hp	187.4	797.7	1304.2	1880.5	2108.3
21-50 hp	100.0	414.1	730.5	1055.9	1055.9
51-100 hp	21.4	103.9	184.9	271.8	353.0
101-200 hp	12.5	66.0	133.9	203.7	270.6
201-500 hp	16.4	149.6	253.2	350.8	448.1
Agriculture					
1-5 hp	0.0	0.0	0.0	0.0	0.0
6-20 hp	0.0	0.0	0.0	0.0	0.0
21-50 hp	0.0	0.0	0.0	0.0	0.0
51-100 hp	4.9	24.0	42.8	62.8	81.6
101-200 hp	1.6	8.5	17.2	26.2	34.8
201-500 hp	1.5	13.6	23.0	31.8	40.6

Table 10.4.2 Net Present Value for NEMA Designs A and B Motors (million 2011$)

7% discount rate	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**	**CSL 5**
Industry					
1-5 hp	345.5	707.1	1093.4	-1302.5	-1836.1
6-20 hp	263.5	809.4	1235.7	-586.2	-765.1
21-50 hp	145.8	460.6	759.9	-79.5	-79.5
51-100 hp	168.7	701.0	1135.6	19.8	-11.1
101-200 hp	113.1	535.2	1024.8	248.7	365.5
201-500 hp	67.3	675.6	1171.6	727.3	975.4
Commercial					
1-5 hp	387.2	685.8	1143.5	-3164.1	-4253.3
6-20 hp	495.3	1337.4	2016.7	-3786.0	-4491.3
21-50 hp	238.5	665.0	1041.9	-1821.9	-1821.9
51-100 hp	45.5	175.7	264.8	-390.7	-515.8
101-200 hp	19.5	89.7	163.6	-111.3	-134.6
201-500 hp	18.3	187.5	314.1	67.1	101.7
Agriculture					
1-5 hp	0.0	0.0	0.0	0.0	0.0
6-20 hp	0.0	0.0	0.0	0.0	0.0
21-50 hp	0.0	0.0	0.0	0.0	0.0
51-100 hp	7.4	25.0	33.3	-133.1	-174.9
101-200 hp	1.6	6.7	11.0	-34.8	-44.3
201-500 hp	0.6	8.1	13.3	-21.0	-25.1

3% discount rate	CSL 1	CSL 2	CSL 3	CSL 4	CSL 5
Industry					
1-5 hp	757.7	1650.9	2528.7	-1765.0	-2606.6
6-20 hp	585.3	1884.3	2900.4	-245.6	-489.2
21-50 hp	342.8	1132.0	1894.3	534.7	534.7
51-100 hp	400.9	1710.5	2827.8	1071.5	1309.7
101-200 hp	283.2	1365.9	2661.9	1598.7	2178.0
201-500 hp	179.0	1758.4	3060.8	2579.4	3387.4
Commercial					
1-5 hp	915.3	1918.4	3121.2	-4528.1	-6203.4
6-20 hp	1197.0	3630.7	5601.2	-4422.9	-5432.5
21-50 hp	596.9	1851.6	3017.5	-1852.5	-1852.5
51-100 hp	117.3	482.6	768.4	-327.0	-442.3
101-200 hp	59.2	286.3	547.3	159.7	235.2
201-500 hp	62.9	614.1	1040.3	756.7	997.7
Agriculture					
1-5 hp	0.0	0.0	0.0	0.0	0.0
6-20 hp	0.0	0.0	0.0	0.0	0.0
21-50 hp	0.0	0.0	0.0	0.0	0.0
51-100 hp	19.8	75.5	113.1	-173.7	-230.0
101-200 hp	5.4	24.8	45.6	-26.8	-32.3
201-500 hp	3.2	34.0	57.7	6.6	11.8

Table 10.4.3 National Energy Savings for NEMA Design C Motors (trillion Btu)

Primary	CSL 1	CSL 2	CSL 3
Industry			
1-5 hp	1.579	2.200	2.846
6-20 hp	1.551	2.232	2.889
21-50 hp	0.905	1.383	1.869
51-100 hp	0.881	1.714	2.478
101-200 hp	0.927	1.651	2.415
Commercial			
1-5 hp	1.603	2.232	2.887
6-20 hp	2.783	4.004	5.184
21-50 hp	1.177	1.798	2.430
51-100 hp	0.228	0.444	0.642
101-200 hp	0.175	0.312	0.457
Agriculture			
1-5 hp	0.000	0.000	0.000
6-20 hp	0.000	0.000	0.000
21-50 hp	0.000	0.000	0.000

51-100 hp	0.044	0.085	0.123
101-200 hp	0.019	0.034	0.049
Full-Fuel Cycle	**CSL 1**	**CSL 2**	**CSL 3**
Industry			
1-5 hp	1.667	2.322	3.003
6-20 hp	1.637	2.355	3.048
21-50 hp	0.955	1.459	1.972
51-100 hp	0.930	1.808	2.614
101-200 hp	0.978	1.742	2.548
Commercial			
1-5 hp	1.691	2.356	3.047
6-20 hp	2.936	4.225	5.470
21-50 hp	1.242	1.897	2.564
51-100 hp	0.241	0.469	0.678
101-200 hp	0.185	0.329	0.482
Agriculture			
1-5 hp	0.000	0.000	0.000
6-20 hp	0.000	0.000	0.000
21-50 hp	0.000	0.000	0.000
51-100 hp	0.046	0.090	0.130
101-200 hp	0.020	0.035	0.052

Table 10.4.4 Net Present Value for NEMA Design C Motors (million 2011$)

7% discount rate	**CSL 1**	**CSL 2**	**CSL 3**
Industry			
1-5 hp	2.890	-2.629	-2.831
6-20 hp	2.771	0.185	0.480
21-50 hp	1.664	1.256	1.724
51-100 hp	1.537	2.025	2.877
101-200 hp	1.599	2.617	3.515
Commercial			
1-5 hp	2.980	-6.705	-7.376
6-20 hp	4.681	-3.731	-3.889
21-50 hp	1.777	-0.702	-0.719
51-100 hp	0.362	0.298	0.439
101-200 hp	0.256	0.414	0.542
Agriculture			
1-5 hp	0.000	0.000	0.000
6-20 hp	0.000	0.000	0.000
21-50 hp	0.000	0.000	0.000
51-100 hp	0.026	-0.044	-0.063

101-200 hp	0.012	0.016	0.014
3% discount rate	**CSL 1**	**CSL 2**	**CSL 3**
Industry			
1-5 hp	6.679	-3.290	-3.313
6-20 hp	6.546	2.246	3.298
21-50 hp	4.080	3.773	5.112
51-100 hp	3.814	5.543	7.870
101-200 hp	4.107	6.814	9.310
Commercial			
1-5 hp	7.983	-9.279	-9.683
6-20 hp	13.113	-0.769	0.683
21-50 hp	5.257	1.589	2.535
51-100 hp	1.055	1.278	1.855
101-200 hp	0.829	1.389	1.902
Agriculture			
1-5 hp	0.000	0.000	0.000
6-20 hp	0.000	0.000	0.000
21-50 hp	0.000	0.000	0.000
51-100 hp	0.108	0.028	0.040
101-200 hp	0.054	0.084	0.104

Table 10.4.5 National Energy Savings for Fire Pump Electric Motors (trillion Btu)

Primary	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**
Industry				
1-5 hp	0.006	0.008	0.011	0.013
6-20 hp	0.185	0.258	0.333	0.361
21-50 hp	0.072	0.106	0.141	0.141
51-100 hp	1.169	1.655	2.216	2.714
101-200 hp	0.954	1.475	1.988	2.457
201-500 hp	0.708	1.190	1.616	2.038
Commercial				
1-5 hp	0.002	0.004	0.005	0.006
6-20 hp	0.005	0.006	0.008	0.009
21-50 hp	0.002	0.003	0.004	0.004
51-100 hp	0.000	0.001	0.001	0.001
101-200 hp	0.000	0.000	0.000	0.000
201-500 hp	0.000	0.000	0.000	0.001
Agriculture				
1-5 hp	0.000	0.000	0.000	0.000
6-20 hp	0.000	0.000	0.000	0.000
21-50 hp	0.000	0.000	0.000	0.000

51-100 hp	0.000	0.000	0.000	0.000
101-200 hp	0.000	0.000	0.000	0.000
201-500 hp	0.000	0.000	0.000	0.000
Full-Fuel Cycle	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**
Industry				
1-5 hp	0.006	0.009	0.012	0.014
6-20 hp	0.195	0.272	0.352	0.381
21-50 hp	0.076	0.112	0.149	0.149
51-100 hp	1.233	1.746	2.338	2.864
101-200 hp	1.006	1.556	2.098	2.592
201-500 hp	0.747	1.255	1.706	2.150
Commercial				
1-5 hp	0.003	0.004	0.005	0.006
6-20 hp	0.005	0.007	0.009	0.010
21-50 hp	0.002	0.003	0.004	0.004
51-100 hp	0.000	0.001	0.001	0.001
101-200 hp	0.000	0.000	0.000	0.001
201-500 hp	0.000	0.000	0.001	0.001
Agriculture				
1-5 hp	0.000	0.000	0.000	0.000
6-20 hp	0.000	0.000	0.000	0.000
21-50 hp	0.000	0.000	0.000	0.000
51-100 hp	0.000	0.000	0.000	0.000
101-200 hp	0.000	0.000	0.000	0.000
201-500 hp	0.000	0.000	0.000	0.000

Table 10.4.6 Net Present Value for Fire Pump Electric Motors (million 2011$)

7% discount rate	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**
Industry				
1-5 hp	-2.594	-3.674	-8.310	-10.487
6-20 hp	-1.499	-2.182	-5.863	-6.607
21-50 hp	-0.614	-0.941	-2.794	-2.794
51-100 hp	1.143	1.481	-0.192	-0.438
101-200 hp	0.956	1.379	0.161	0.086
201-500 hp	0.639	1.049	0.297	0.386
Commercial				
1-5 hp	-2.252	-2.949	-9.700	-12.263
6-20 hp	-3.293	-4.645	-14.543	-16.304
21-50 hp	-1.440	-2.178	-7.217	-7.217
51-100 hp	-0.334	-0.523	-1.718	-2.178
101-200 hp	-0.155	-0.263	-0.815	-1.027

201-500 hp	-0.190	-0.332	-0.902	-1.127
Agriculture				
1-5 hp	0.000	0.000	0.000	0.000
6-20 hp	0.000	0.000	0.000	0.000
21-50 hp	0.000	0.000	0.000	0.000
51-100 hp	-0.079	-0.123	-0.403	-0.510
101-200 hp	-0.022	-0.038	-0.117	-0.147
201-500 hp	-0.021	-0.036	-0.097	-0.121
3% discount rate	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**
Industry				
1-5 hp	-6.436	-9.292	-18.784	-23.687
6-20 hp	-3.343	-4.924	-12.094	-13.656
21-50 hp	-1.327	-2.043	-5.627	-5.627
51-100 hp	3.680	4.909	2.471	2.585
101-200 hp	3.063	4.525	2.893	3.317
201-500 hp	2.118	3.515	2.653	3.349
Commercial				
1-5 hp	-4.860	-6.506	-19.450	-24.580
6-20 hp	-6.728	-9.544	-28.303	-31.741
21-50 hp	-2.894	-4.380	-13.908	-13.908
51-100 hp	-0.674	-1.050	-3.312	-4.200
101-200 hp	-0.313	-0.526	-1.571	-1.984
201-500 hp	-0.382	-0.664	-1.746	-2.183
Agriculture				
1-5 hp	0.000	0.000	0.000	0.000
6-20 hp	0.000	0.000	0.000	0.000
21-50 hp	0.000	0.000	0.000	0.000
51-100 hp	-0.159	-0.247	-0.776	-0.984
101-200 hp	-0.045	-0.076	-0.225	-0.285
201-500 hp	-0.041	-0.072	-0.188	-0.235

Table 10.4.7 National Energy Savings Summary (quads)

Primary	CSL 1	CSL 2	CSL 3	CSL 4	CSL 5
NEMA Design A and B	0.972	4.414	7.527	10.836	13.005
NEMA Design C	0.012	0.018	0.024	-	-
Fire Pump Electric Motors	0.003	0.005	0.006	0.008	-
All Motors[h]	0.987	4.437	7.558	10.843	13.005
Full-Fuel Cycle	CSL 1	CSL 2	CSL 3	CSL 4	CSL 5
NEMA Design A and B	1.026	4.657	7.942	11.433	13.722
NEMA Design C	0.013	0.019	0.026	-	-
Fire Pump Motors	0.003	0.005	0.007	0.008	-
All Motors[h]	1.041	4.681	7.974	11.441	13.722

Table 10.4.8 Net Present Value Summary (billion 2011$)

7% discount rate	CSL 1	CSL 2	CSL 3	CSL 4	CSL 5
NEMA Design A and B	2.318	7.070	11.423	-10.368	-12.710
NEMA Design C	0.021	-0.007	-0.005	-	-
Fire Pump Electric Motors	-0.010	-0.014	-0.052	-0.061	-
All Motors[h]	2.329	7.049	11.366	-10.429	-12.710
3% discount rate	CSL 1	CSL 2	CSL 3	CSL 4	CSL 5
NEMA Design A and B	5.526	18.420	30.186	-6.634	-8.634
NEMA Design C	0.054	0.009	0.020	-	-
Fire Pump Electric Motors	-0.018	-0.026	-0.098	-0.114	-
All Motors[h]	5.561	18.403	30.108	-6.748	-8.634

10.4.2 Scenario Analysis

DOE also performed a scenario analysis to assess how changes in economic growth would affect the former NPV results reported in Table 10.4.8. Table 10.4.9 and Table 10.4.10 present NPV results for both the low- and high economic growth scenarios.

Table 10.4.9 Net Present Value Summary for the Low Economic Growth Scenario (billion 2011$)

7% discount rate	CSL 1	CSL 2	CSL 3	CSL 4	CSL 5
NEMA Design A and B	1.790	5.257	8.439	-10.171	-12.425
NEMA Design C	0.015	-0.008	-0.008	-	-
Fire Pump Electric Motors	-0.008	-0.012	-0.044	-0.051	-
All Motors[h]	1.797	5.236	8.387	-10.223	-12.425
3% discount rate	CSL 1	CSL 2	CSL 3	CSL 4	CSL 5
NEMA Design A and B	4.131	13.326	21.728	-9.536	-11.983
NEMA Design C	0.039	0.001	0.007	-	-
Fire Pump Electric Motors	-0.016	-0.023	-0.082	-0.096	-
All Motors[h]	4.154	13.303	21.652	-9.632	-11.983

Table 10.4.10 Net Present Value Summary for the High Economic Growth Scenario (billion 2011$)

7% discount rate	CSL 1	CSL 2	CSL 3	CSL 4	CSL 5
NEMA Design A and B	2.892	9.082	14.744	-10.144	-12.491
NEMA Design C	0.026	-0.005	-0.002	-	-
Fire Pump Electric Motors	-0.011	-0.016	-0.060	-0.070	-
All Motors[h]	2.907	9.061	14.682	-10.214	-12.491
3% discount rate	CSL 1	CSL 2	CSL 3	CSL 4	CSL 5
NEMA Design A and B	7.001	23.872	39.252	-2.885	-4.265
NEMA Design C	0.069	0.019	0.035	-	-
Fire Pump Electric Motors	-0.020	-0.029	-0.114	-0.132	-
All Motors[h]	7.050	23.862	39.173	-3.017	-4.265

10.4.3 Sensitivity Analysis

Besides calculating NES and NPV values for the inputs described in sections 10.2.2 and 10.3.2 above, DOE performed a sensitivity analysis for some of those inputs, namely the annual hours of operation, MSP and repair cost. While changes in the annual hours of operation affect both the NES and NPV, a variation in the MSP and repair cost impacts only the NPV. Table 10.4.11 through Table 10.4.14 summarize the impacts that a change of ±10 percent in these variables has on the former NES and NPV values, as reported in Table 10.4.7 and Table 10.4.8.

Table 10.4.11 National Energy Savings Variation in Response to ±10 Percent Changes in Hours of Operation* (trillion Btu)

Primary	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**	**CSL 5**
NEMA Design A and B	±97.2	±441.4	±752.7	±1083.6	±1300.5
NEMA Design C	±1.2	±1.8	±2.4	-	-
Fire Pump Electric Motors	±0.3	±0.5	±0.6	±0.8	-
All Motors[h]	±98.7	±443.7	±755.8	±1084.3	±1300.5
Full-Fuel Cycle	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**	**CSL 5**
NEMA Design A and B	±102.6	±465.7	±794.2	±1143.3	±1372.2
NEMA Design C	±1.3	±1.9	±2.6	-	-
Fire Pump Electric Motors	±0.3	±0.5	±0.7	±0.8	-
All Motors[h]	±104.1	±468.1	±797.4	±1144.1	±1372.2

* NES and hours of operation are positively correlated, which means that a positive increase in NES results from a positive increase in hours of operation.

Table 10.4.12 Net Present Value Variation in Response to ±10 Percent Changes in Hours of Operation* (million 2011$)

7% discount rate	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**	**CSL 5**
NEMA Design A and B	±281.9	±1257.2	±2134.8	±3071.6	±3669.3
NEMA Design C	±3.5	±5.2	±7.0	-	-
Fire Pump Electric Motors	±0.6	±0.9	±1.2	±1.5	-
All Motors[h]	±285.9	±1263.3	±2142.9	±3073.1	±3669.3
3% discount rate	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**	**CSL 5**
NEMA Design A and B	±657.8	±2950.4	±5016.3	±7218.4	±8627.7
NEMA Design C	±8.1	±12.3	±16.4	-	-
Fire Pump Electric Motors	±1.6	±2.5	±3.3	±4.0	-
All Motors[h]	±667.5	±2965.1	±5036.0	±7222.4	±8627.7

* NPV and hours of operation are positively correlated, which means that a positive increase in NPV results from a positive increase in hours of operation.

Table 10.4.13 Net Present Value Variation in Response to ±10 Percent Changes in Manufacturer Selling Price* (million 2011$)

7% discount rate	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**	**CSL 5**
NEMA Design A and B	±27.7	±367.0	±729.5	±3557.2	±4257.0
NEMA Design C	±1.0	±5.2	±6.6	-	-
Fire Pump Electric Motors	±0.9	±1.4	±5.0	±5.9	-
All Motors[h]	±29.7	±373.6	±741.1	±3563.1	±4257.0
3% discount rate	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**	**CSL 5**
NEMA Design A and B	±51.8	±684.7	±1361.1	±6636.8	±7942.4
NEMA Design C	±1.9	±9.7	±12.2	-	-
Fire Pump Electric Motors	±1.7	±2.6	±9.4	±10.9	-
All Motors[h]	±55.4	±697.0	±1382.7	±6647.7	±7942.4

* NPV and MSP are negatively correlated, which means that a positive increase in NPV results from a negative increase in MSP.

Table 10.4.14 Net Present Value Variation in Response to ±10 Percent Changes in Repair Cost* (million 2011$)

7% discount rate	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**	**CSL 5**
NEMA Design A and B	±15.8	±109.3	±195.1	±289.6	±368.4
NEMA Design C	±0.1	±0.3	±0.5	-	-
Fire Pump Electric Motors	±0.5	±0.7	±1.0	±1.2	-
All Motors[h]	±16.4	±110.3	±196.6	±290.8	±368.4
3% discount rate	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**	**CSL 5**
NEMA Design A and B	±41.2	±285.7	±510.0	±756.9	±961.3
NEMA Design C	±0.4	±0.9	±1.3	-	-
Fire Pump Electric Motors	±1.4	±2.2	±2.9	±3.6	-
All Motors[h]	±43.0	±288.7	±514.3	±760.5	±961.3

* NPV and repair cost are negatively correlated, which means that a positive increase in NPV results from a negative increase in repair cost.

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