PRELIMINARY TECHNICAL SUPPORT DOCUMENT EXECUTIVE SUMMARY

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ES.1 OVERVIEW OF CURRENT ACTIVITIES

The Energy Policy and Conservation Act (EPCA), 42 U.S.C. § 6311, *et seq.*, as amended by the Energy Policy Act of 1992 (EPACT) established energy conservation standards and test procedures for certain commercial and industrial electric motors manufactured (alone or as a component of another piece of equipment) after October 24, 1997. Then, in December 2007, Congress passed into law the Energy Independence and Security Act of 2007 (EISA 2007) (Pub. L. No. 110–140). Section 313(b)(1) of EISA 2007 updated the energy conservation standards for those electric motors already covered by EPCA and established energy conservation standards for a larger scope of motors not previously covered. (42 U.S.C. 6313(b)(2))

EPCA also directs the Secretary of Energy to publish a final rule no later than 24 months after the effective date of the previous final rule to determine whether to amend the standards in effect for such product. Any such amendment shall apply to electric motors manufactured after a date which is five years after –

(i) the effective date of the previous amendment; or
(ii) if the previous final rule did not amend the standards, the earliest date by which a previous amendment could have been effective. (42 U.S.C. 6313(b)(4)(B))

EISA 2007, which went into effect on December 19, 2010, constitutes the most recent amendment to EPCA and energy conservation standards for electric motors. DOE will determine whether to promulgate amended energy conservation standards for electric motors and, if so, what level the new standards should be set at based on an in-depth consideration of the technological feasibility, economic justification, and energy savings of candidate standards levels as required by section 325 of EPCA. (42 U.S.C. 6295(o)-(p), 6316(a)) Any such amended standards that DOE establishes would take effect December 19, 2015.

This executive summary describes current activities and key results from the preliminary analyses that DOE conducted in its review of potential amendments to the energy conservation standards for electric motors. Furthermore, the executive summary identifies issues about which DOE seeks comments from interested parties. These issues are addressed in more detail in chapter 2 of the preliminary technical support document (preliminary TSD) and will be discussed in a future public meeting.

To evaluate and consider impacts under the seven EPCA factors for economic justification (42 U.S.C. 6295(o)(2)(B)(i), 6316(a)), DOE conducts a detailed analysis of regulatory impacts on a product and presents them in a technical support document (preliminary TSD). Figure ES.1.1 summarizes the analytical components of this regulatory analysis methodology. The focus of this figure is the center column, identified as “Analyses.” The columns labeled “Key Inputs” and “Key Outputs” show how the analyses fit into the rulemaking process, and how the analyses relate to each other. Key inputs are the types of data and other information that the analyses require. Some key inputs exist in public databases; DOE collects other inputs from interested parties or persons with special knowledge and expertise. Key outputs are analytical results that feed directly into the standards-setting process. Arrows connecting analyses show types of information that feed from one analysis to another.

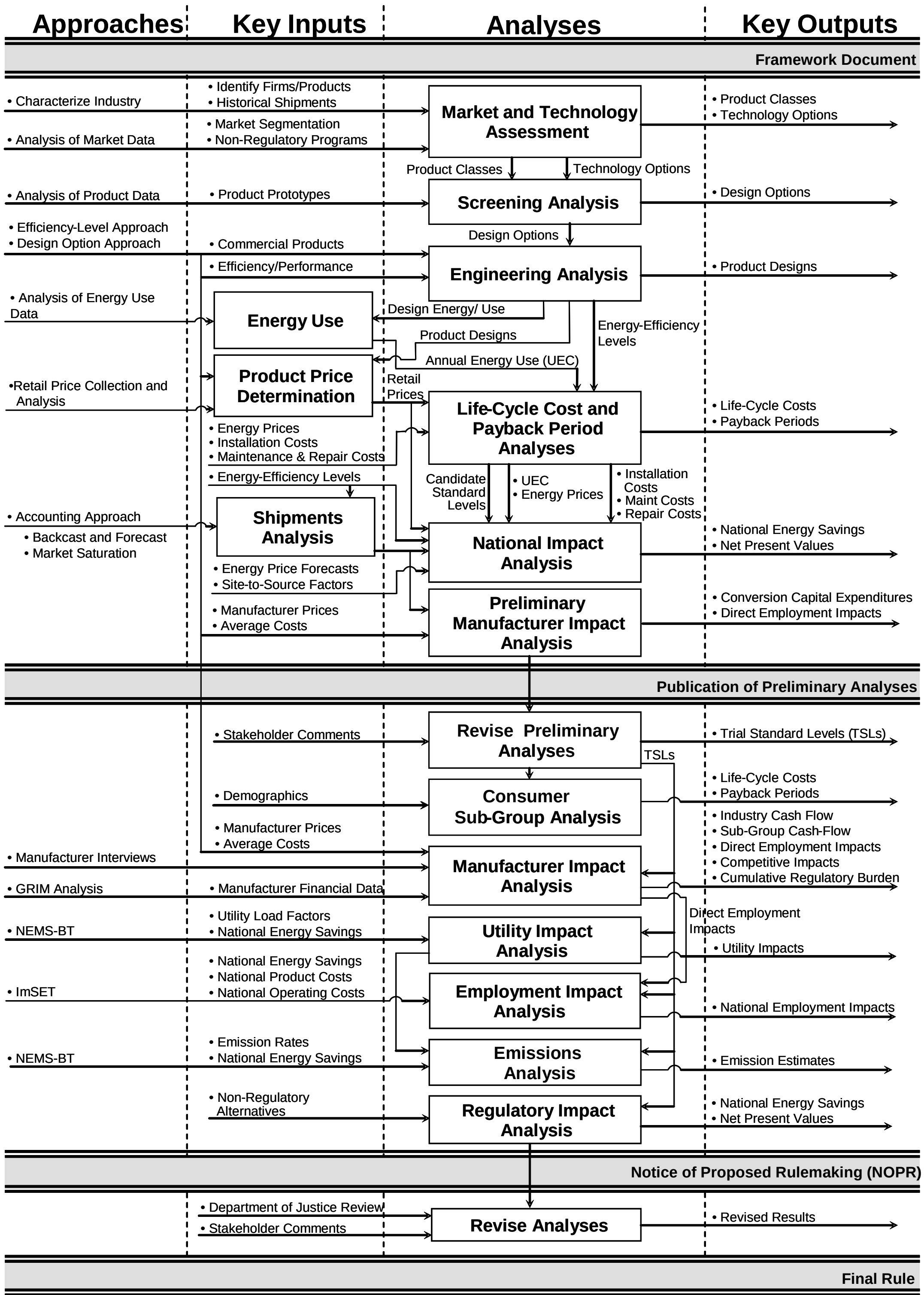

Figure ES.1.1 Flow Diagram of Electric Motor Rulemaking Analyses

ES.2 OVERVIEW OF THE PRELIMINARY ANALYSES AND THE PRELIMINARY TECHNICAL SUPPORT DOCUMENT

DOE is publishing a notice of public meeting (NOPM) in the Federal Register, which announces the availability of the preliminary TSD, the date of the public meeting, and information pertaining to the public meeting. In addition, the NOPM highlights the major preliminary analyses DOE has developed at this stage of the rulemaking.

The preliminary TSD describes each analysis in detail, providing detailed descriptions of inputs, sources, methodologies, and results. Chapter 2 of the preliminary TSD provides an overview of each preliminary analysis, the comments DOE received in response to the framework document, and DOE's responses to those comments. The remaining chapters of the preliminary TSD, which are described later, address the preliminary analyses performed:

Chapter 3: A market and technology assessment that characterizes the relevant product markets and technology options, including prototype designs.

Chapter 4: A screening analysis that reviews each technology option to determine whether it (1) is technologically feasible, (2) is practicable to manufacture, install, and service, (3) would adversely affect product utility or product availability, or (4) would have adverse impacts on health and safety.

Chapter 5: An engineering analysis that develops cost-efficiency relationships estimating the manufacturer's cost of achieving increased efficiency. DOE determines the increased cost to the consumer through an analysis of engineering markups, which convert manufacturer production cost to manufacturer selling price (MSP).

Chapter 6: A markups analysis that converts the estimated MSPs derived from the engineering analysis to installed prices.

Chapter 7: An energy use analysis that determines the annual energy use of the considered products.

Chapter 8: Life-cycle cost (LCC) and payback period (PBP) analyses that calculate, at the consumer level, the discounted savings in operating costs (less maintenance and repair costs) throughout the estimated average life of the covered products, compared to any increase in the installed cost for the products likely to result directly from the imposition of a given standard.

Chapter 9: A shipments analysis that projects product shipments, which are then used to calculate the national impacts of standards on energy, net present value (NPV), and future manufacturer cash flows.

Chapter 10: An assessment of the aggregate impacts at the national level of potential energy conservation standards for the considered products, as measured by the NPV of total consumer economic impacts and the national energy savings (NES).

Chapter 11: A customer subgroup analysis that evaluates the impacts of standards on identifiable groups of customers, such as customers of different business types, which may be disproportionately affected by an energy conservation standard.

Chapter 12: A preliminary manufacturer impact analysis (MIA) that assesses the potential impacts of energy conservation standards on manufacturers, such as effects on expenditures for capital conversion, marketing costs, shipments, and research and development costs.

Chapter 13: An employment impact analysis that examines the effects of energy conservation standards on national employment.

Chapter 14: A utility impact analysis that examines impacts of energy conservation standards on the generation capacity of electric utilities.

Chapter 15: An emissions analysis that evaluates the reduced power plant emissions resulting from reduced consumption of electricity.

Chapter 16: A monetization of emission reduction benefits resulting from reduced emissions associated with potential amended standards.

Chapter 17: A regulatory impact analysis that: (1) identifies and seeks to mitigate overlapping effects of regulations on manufacturers and (2) addresses the potential for non-regulatory approaches to supplant or augment energy conservation standards.

ES.3 KEY RESULTS FROM THE ANALYSES

The following sections describe in detail the key analyses DOE performed in support of the preliminary TSD.

ES.3.1 Market and Technology Assessment

When initiating an energy conservation standards rulemaking, DOE develops information on the present and past industry structure and market characteristics for the equipment concerned. This activity assesses the industry and equipment both quantitatively and qualitatively, based on publicly available information. For the equipment in the preliminary analyses, DOE addressed the following: (1) manufacturer market share and characteristics, (2) existing regulatory and non-regulatory initiatives to improve the efficiency of the equipment, and (3) trends in the equipment's characteristics and retail markets. This information serves as resource material throughout the rulemaking.

DOE reviewed literature and interviewed manufacturers to get an overall understanding of the electric motors industry in the United States. Industry publications, trade journals, government agencies, and trade organizations provided the bulk of the information obtained regarding: (1) manufacturers and their market shares, (2) shipments by equipment class, (3) equipment information, and (4) industry trends. The appropriate sections of preliminary TSD chapters 2 and 3 describe the analyses and resulting information.

DOE typically uses information about existing and past technology options and prototype designs to determine which technologies and combinations of technologies manufacturers use to attain higher performance levels. In consultation with interested parties, DOE develops a list of technologies for consideration. Initially, these technologies encompass all of those options that might for improve equipment efficiency. DOE developed its list of technology options for electric motors from its examination of technical documents and through consultation with manufacturers and industry experts.

ES.3.2 Screening Analysis

The screening analysis (chapter 4) examines whether various technologies: (1) are technologically feasible; (2) are practicable to manufacture, install, and service; (3) have an adverse impact on product utility or availability; or (4) have adverse impacts on health and safety. DOE develops an initial list of efficiency-enhancement options (i.e., technology options) from those identified as "technologically feasible" in the technology assessment. In consultation with interested parties, DOE then reviews the list to determine if these technologies are practicable to manufacture, install, and service; would adversely affect product utility or availability; or would have adverse impacts on health and safety. DOE removes from the list those technology options for which no energy consumption information is available and technology options whose energy consumption could not be adequately measured by the existing DOE test procedure. After DOE examines all of the technology options and pares them down in the screening analysis, it uses the remaining design options as inputs to estimate the characteristics and the cost of higher efficiency equipment in the engineering analysis.

ES.3.3 Engineering Analysis

The engineering analysis (chapter 5) establishes the relationship between the MSP and product efficiency. This relationship serves as the basis for cost/benefit calculations in terms of individual consumers, manufacturers, and the Nation. This chapter discusses the equipment classes DOE analyzed, the representative baseline units, the incremental efficiency levels, the methodology DOE used to develop the MSP, the cost-efficiency curves for equipment classes analyzed, and the methodology DOE used to scale those results to other equipment classes of electric motors that were not analyzed.

ES.3.3.1 Equipment Classes Analyzed

Because of the large number of electric motor equipment classes, DOE did not analyze each one in the engineering analysis. Instead, DOE analyzed five representative equipment classes: three from equipment class group 1 (NEMA Design A and B motors) and two from equipment class group 2 (NEMA Design C motors). The equipment class group 3 (fire pump motors) analysis will be based on the data from equipment class group 1 representative units because of the similarities between fire pump electric motors and NEMA Design B motors. When selecting these groups, DOE used catalog data, discussions with industry experts, and the Framework Document. After analyzing this information, DOE reached the tentative conclusion that the selected motor groups were representative of the commercial and industrial electric motor market which made them reasonable selections for the purposes of conducting the engineering analysis. The motors presented in Table ES.3.1 are the five representative units DOE analyzed. The left three columns provide the three characteristics of an electric motor that define its equipment class – namely, motor category, horsepower and number of poles. The fourth column denotes the frame series of the analyzed motor.

Table ES.3.1 Design Characteristics of the Five Representative Units Analyzed

Motor Category	Horsepower	Number of Poles	Frame Series
NEMA Design B	5	4	184T
NEMA Design B	30	4	286T
NEMA Design B	75	4	365T
NEMA Design C	5	4	184T
NEMA Design C	50	4	326T

DOE requests comment on its selection of representative units for equipment class group 1, Design A and B motors from 1-500 horsepower, and equipment class group 2, Design C motors from 1-200 horsepower. DOE also requests comment on basing its analysis of equipment class group 3, fire pump electric motors, on the analysis of equipment class group 1 representative units.

ES.3.3.2 Engineering Analysis Results

For each NEMA Design B representative unit, DOE purchased four electric motors at four increasing efficiency levels[a]. The purchased motors included a baseline design at the minimum efficiency commercially available, while considering the expanded scope of coverage, a design at the EPACT 1992 level, a design at the NEMA Premium level, and a design at the maximum efficiency commercially available for that motor rating. DOE then used software modeling to create a fifth and sixth motor design for each of the three NEMA Design B electric motors. These additional designs had efficiencies corresponding to an incremental efficiency level and a maximum technologically feasible (“max tech”) efficiency level. DOE assigned each of these efficiency levels a candidate standard level (CSL) number from 0-5 with the baseline motor being assigned CSL 0 and the max-tech software modeled motor being assigned CSL 5. See Table ES.3.2 for a layout of the CSLs and their efficiency representations.

Table ES.3.2 NEMA Design B Motor Candidate Standard Levels

Motor Designation	Efficiency Level
CSL 0	Minimum Commercially Available
CSL 1	EPACT 1992
CSL 2	NEMA Premium
CSL 3	Maximum Commercially Available

[a] For the 30 horsepower representative unit, DOE purchased three electric motors at different efficiency levels, and used software modeling to simulate motors at the remaining efficiency levels.

CSL 4	Incremental
CSL 5	Maximum Technology

For the NEMA Design C representative units, DOE purchased one baseline motor and used software to model three additional designs with higher efficiencies than the efficiency of the baseline motor. DOE used this approach because NEMA Design C motors constitute a small portion of the electric motor market with limited product selection and DOE was unable to locate any commercially available units with increased efficiency levels. The NEMA Design C motors were assigned CSL numbers from 0-3 with CSL 0 representing EPACT 1992 efficiency levels and CSL 3 representing the max-tech efficiency level. See Table ES.3.3 and Table ES.3.4 for a layout of the CSLs and their efficiency representations.

Table ES.3.3 Design C 5 Horsepower Motor Candidate Standard Levels

Motor Designation	Efficiency Level
CSL 0	EPACT 1992
CSL 1	NEMA Premium
CSL 2	Incremental
CSL 3	Maximum Technology

Table ES.3.4 NEMA Design C 50 Horsepower Motor Candidate Standard Levels

Motor Designation	Efficiency Level
CSL 0	EPACT 1992
CSL 1	Incremental
CSL 2	NEMA Premium
CSL 3	Maximum Technology

DOE used a consistent methodology and pricing scheme including material, labor costs and manufacturer markups to develop MSPs for the baseline and incrementally more efficient electric motor designs. This methodology included tearing down the motors, weighing components, and estimating the material costs based on material pricing. DOE used this bottoms-up derived and manufacturer marked-up selling prices throughout this section. The engineering analysis results are a series of MSP-versus-efficiency curves that represent the five motor types analyzed from the representative equipment classes. The five graphs shown in Figure ES.3.1 through Figure ES.3.5 provide the MSP-versus-efficiency curves and Table ES.3.6 through Table ES.3.14 present the tabulated results.

In determining the relationship between MSP and energy efficiency for electric motors, DOE estimated the increase in MSP associated with technological changes that increase the efficiency of the baseline models. DOE developed cost estimates for the engineering analysis from information received from subject matter experts with many years experience in the field, manufacturers' suggestions, and input from other industry-related experts, including material suppliers.

NEMA Design B, 5 Horsepower, 4-Pole, Enclosed Frame Motor

Figure ES.3.1 presents the relationship between the MSP and full-load efficiency for the 5 horsepower, Design B, 4-pole enclosed polyphase motor analyzed. Using tear-down results for CSLs 0-3, DOE determined that the manufacturer of those motors used various combinations of stack length increases, electrical material such as copper or electrical steel, and rotor cage design changes to increase the electric motor's efficiency level. The max-tech software modeled CSL 5 and utilized a die-cast copper conductor in the rotor. Also, DOE assumed a hand-wound labor hour amount for the two software modeled CSLs (CSL 4 and 5). The increased labor hour amounts account for the larger than usual increase in the MSPs for the higher CSLs as illustrated in Figure ES.3.1.

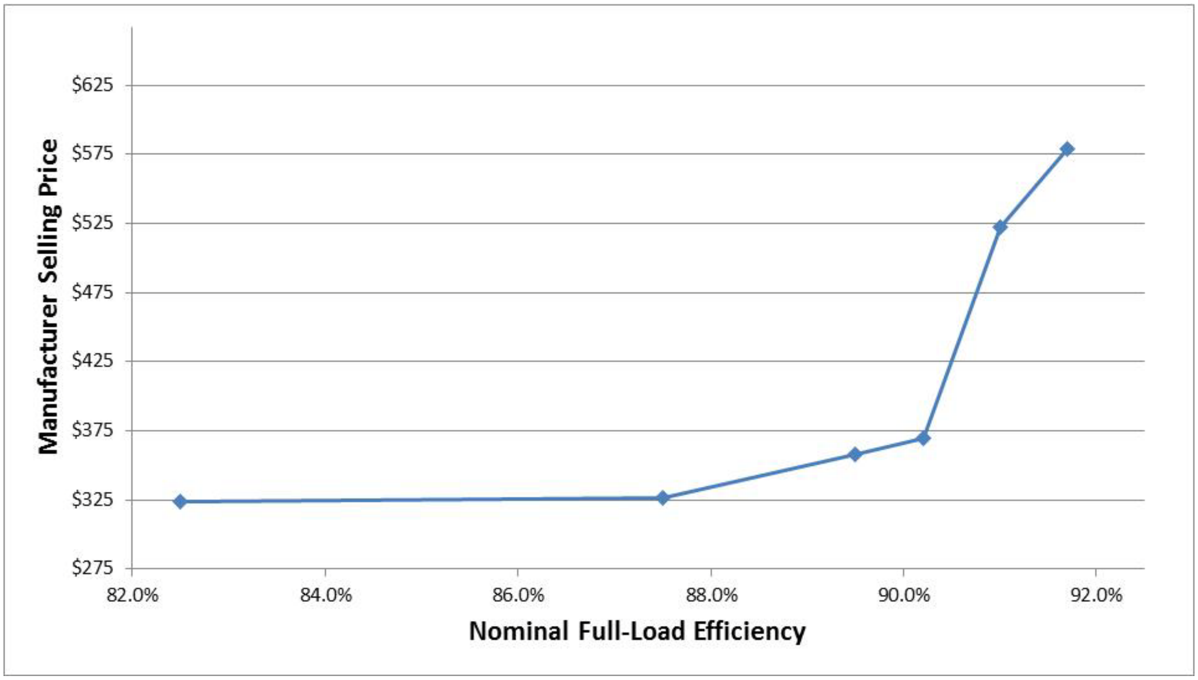

Figure ES.3.1 NEMA Design B, 5 Horsepower, 4-Pole, Enclosed Frame Motor Engineering Analysis Curve

Table ES.3.5 presents the same engineering analysis results in tabular form, including the nominal full-load efficiency values and the MSPs. From CSL 0 to 3, DOE found that the full-load efficiency would increase 7.7 nominal percentage points over the baseline, CSL 0, which represents a 49 percent reduction in motor losses. When moving from CSL 3 to 4 and from CSL 4 to 5, MSP increases by 41 percent and 11 percent, respectively, for consecutive loss reductions of roughly 10 percent. Again, the large price increases when getting to CSLs 4 and 5 are a result of the use of hand-wound labor hour assumptions and the use of low-loss electrical steels.

Table ES.3.5 Efficiency and Manufacturer Selling Price Data for the NEMA Design B 5 Horsepower Motor

CSL	Nominal Full-Load Efficiency (%)	MSP ($)
0	82.5	324
1	87.5	326
2	89.5	358
3	90.2	370
4	91.0	523
5	91.7	579

Table ES.3.6 presents some of the design and performance specifications associated with the six 5-horsepower NEMA Design B motors presented in Table ES.3.5 including stator copper weight, rotor conductor weight, and electrical steel weight.

Table ES.3.6 NEMA Design B 5 Horsepower, 4-Pole, Enclosed Frame Motor Characteristics

Parameter	Units	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4	CSL 5
Efficiency	**%**	82.5	87.5	89.5	90.2	91.0	91.7
Line Voltage	**V**	460	460	460	460	460	460
Full Load Speed	**RPM**	1,745	1,745	1,760	1,755	1,773	1,776
Full Load Torque	**Nm**	20.3	20.4	20.3	20.4	20.1	20.1
Current	**A**	6.9	6.5	6.3	6.2	6.3	6.0
Steel	**-**	M56	M47	M47	M47	M36	M36
Rotor Conductor Material	**-**	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Copper
Approximate Slot Fill	**%**	43.5%	57.2%	70.0%	68.6%	82.4%	85.2%
Stator Wire Gauge	**AWG**	19	19	19	20	20	20
Stator Copper Weight	**lbs**	8.4	10.1	10.1	12.2	14.4	14.4
Rotor Conductor Weight	**lbs**	2.63	2.87	2.6	3.42	2.7	9.1
Stack Length	**In**	2.8	3.47	5.14	4.65	5.32	5.32
Housing Weight	**lbs**	8	9	22	12	14	14

NEMA Design B, 30 Horsepower, 4-Pole, Enclosed Frame Motor

Figure ES.3.2 presents the relationship between the MSP and full-load efficiency for the 30 horsepower, Design B, 4-pole enclosed polyphase motor analyzed. Using tear-down results for CSLs 0 through 3, DOE determined that the manufacturer of these motors used a combination of material grade, material quantities, and design changes to increase the electric motor's efficiency.

DOE used software modeling to develop CSL 4. For this design, DOE used a copper rotor and low-loss electrical steel to achieve efficiencies higher than the most efficient purchased motor, CSL 3. DOE was unable to increase the efficiency a full NEMA band greater than CSL 4 and therefore the 30 horsepower Design B representative equipment class does not have a CSL 5.

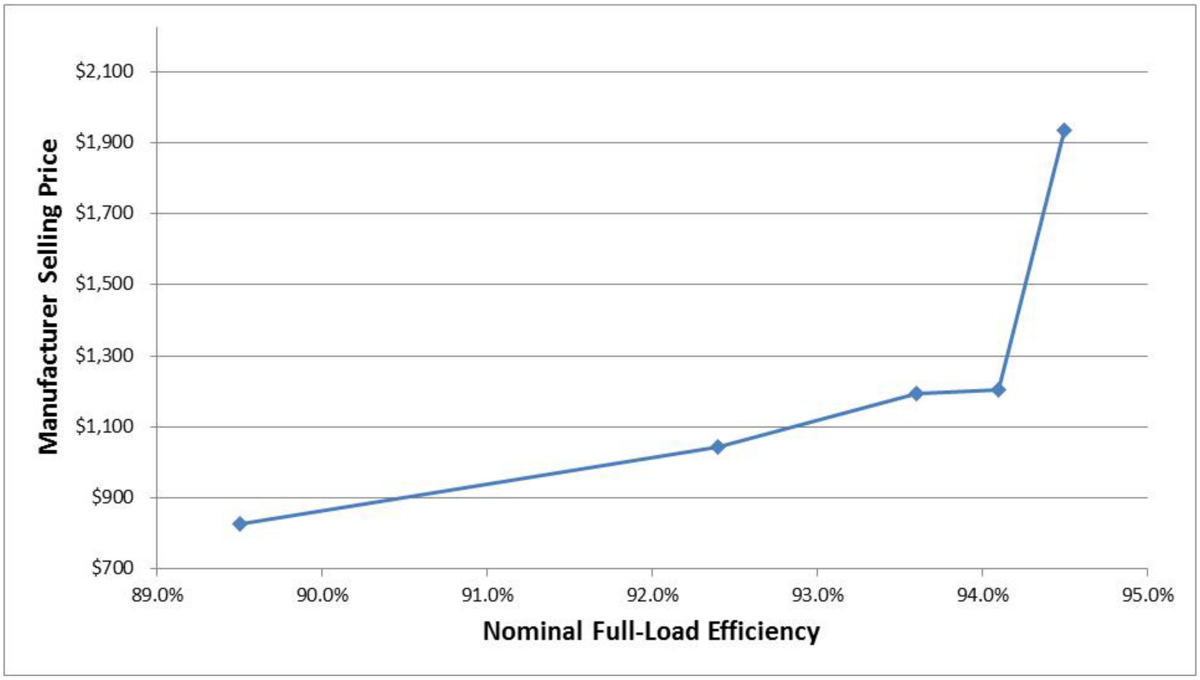

Figure ES.3.2 NEMA Design B, 30 Horsepower, 4-Pole, Enclosed Frame Motor Engineering Analysis Curve

Table ES.3.7 presents the same engineering analysis results in a tabular form, including the full-load efficiency values and the MSPs. From CSL 0 through 3, DOE found that the full-load efficiency would increase 4.6 nominal percentage points over the baseline, CSL 0, which represents about a 47 percent reduction in motor losses. The increase in MSP to move from CSL 0 to CSL 3 is $377, or about a 46 percent increase in MSP over CSL 0. Moving from CSL 3 to CSL 4 provides a 7 percent reduction in motor losses for a MSP increase of $732 or about a 61 percent MSP increase over CSL 3.

Table ES.3.7 Efficiency and Manufacturer Selling Price Data for the NEMA Design B 30 Horsepower Motor

CSL	Nominal Full-Load Efficiency (%)	MSP ($)
0	89.5	827
1	92.4	1,044
2	93.6	1,193
3	94.1	1,204
4	94.5	1,936

Table ES.3.8 presents some of the design and performance specifications associated with the four 30 horsepower designs presented in Table ES.3.7.

Table ES.3.8 NEMA Design B 30 Horsepower, 4-Pole, Enclosed Frame Motor Characteristics

Parameter	Units	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
Efficiency	**%**	89.5	92.4	93.6	94.1	94.5
Line Voltage	**V**	230	460	460	460	460
Full Load Speed	**RPM**	1,755	1,765	1,768	1,770	1,784
Full Load Torque	**Nm**	121.6	121.4	120.8	120.6	119.6
Current	**A**	37	37	36	36	37
Steel	**-**	M56	M56/M47	M47	M47	M36
Rotor Conductor Material	**-**	Aluminum	Aluminum	Aluminum	Aluminum	Copper
Approximate Slot Fill	**%**	48.4	84.0	70.0	70.0	83.2
Stator Wire Gauge	**AWG**	18	17	16	18	18
Stator Copper Weight	**lbs**	20.2	43.5	45.2	47.7	74.5
Rotor Conductor Weight	**lbs**	8.25	9.5	7.5	13.66	42.6
Stack Length	**In**	7.88	5.53	6.00	6.74	7.00
Housing Weight	**lbs**	21	130	131	147	79

NEMA Design B, 75 Horsepower, 4-Pole, Enclosed Frame Motor

Figure ES.3.3 presents the relationship between the MSP and full-load efficiency for the 75 horsepower, Design B, 4-pole enclosed polyphase motor analyzed.

Using tear-down results for CSLs 0 through 3, DOE determined that the manufacturer of these electric motors increased the stack length and other material amounts to increase the electric motor's efficiency levels from 93.0 percent to 95.8 percent. The torn-down electric motor representing CSL 3 used increased rotor aluminum and stator copper as well as an increased stack length to achieve 95.8 percent efficiency. To develop CSL 4 and 5, DOE used die-cast copper conductors in the rotors and increased the stack lengths for each CSL 4 and 5. The use of die-cast copper rotors and change from machine winding to hand winding labor hours account for the larger-than-typical price increases for CSL 4 and 5 when compared to lower CSLS for the 75 horsepower Design B representative units.

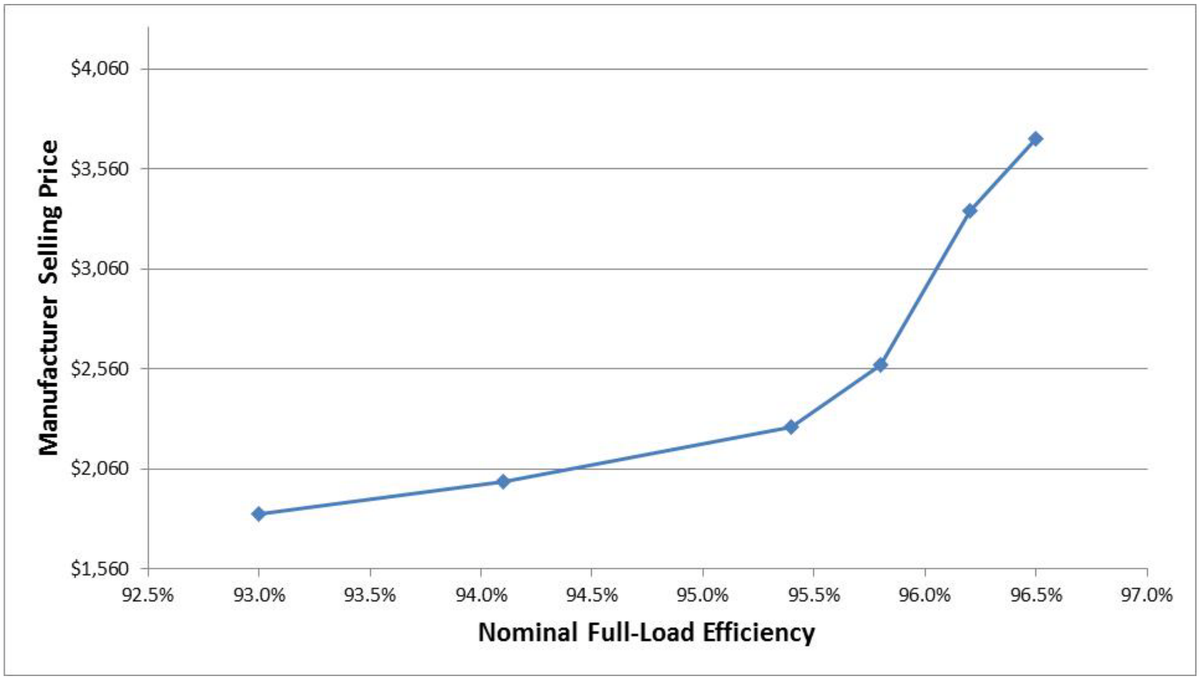

Figure ES.3.3 NEMA Design B, 75 Horsepower, 4-Pole, Enclosed Frame Motor Engineering Analysis Curve

Table ES.3.9 presents the same engineering analysis results in a tabular form, including the nominal full-load efficiency values and the MSPs. Moving from CSL 0 to CSL 3, DOE found that the full-load efficiency would increase 2.8 nominal percentage points over the baseline, CSL 0, which represents about a 42 percent reduction in motor losses. The increase in MSP to move from CSL 0 to CSL 3 is about $748 or about a 41 percent increase in MSP over CSL 0. Moving from CSL 3 to CSL 4 provides a 10 percent reduction in motor losses for a MSP increase of $772 or about a 30 percent MSP increase over the CSL 3 electric motor, and to increase the efficiency from CSL 4 to the max-tech efficiency of CSL 5 there is a 10 percent reduction in motor losses for a 11 percent increase in MSP of $359.

Table ES.3.9 Efficiency and Manufacturer Selling Price Data for the NEMA Design B 75 Horsepower Motor

CSL	Nominal Full-Load Efficiency (%)	MSP ($)
0	93.0	1,833
1	94.1	1,994
2	95.4	2,270
3	95.8	2,581
4	96.2	3,353
5	96.5	3,712

Table ES.3.10 presents some of the design and performance specifications associated with the six 75-horsepower designs presented in Table ES.3.9.

Table ES.3.10 NEMA Design B 75 Horsepower, 4-Pole, Enclosed Frame Motor Characteristics

Parameter	Units	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4	CSL 5
Efficiency	**%**	93.0	94.1	95.4	95.8	96.2	96.5
Line Voltage	**V**	460	460	460	460	460	460
Full Load Speed	**RPM**	1,775	1,785	1,781	1,785	1,788	1,789
Full Load Torque	**Nm**	299.8	299.8	302.3	300.8	299.6	299.6
Current	**A**	88	91.8	89.4	88.6	89.8	91.9
Steel	**-**	M56	M47	M47	M47	M36	M36
Rotor Conductor Material	**-**	Aluminum	Aluminum	Aluminum	Aluminum	Copper	Copper
Approximate Slot Fill	**%**	48.0	44.5	70.0	70.0	85.1	83.4
Stator Wire Gauge	**AWG**	17	12	12	15	14	14
Stator Copper Weight	**lbs**	77.8	71	82	136	127	160
Rotor Conductor Weight	**lbs**	31.0	20.7	27.3	38.5	79	84.3
Stack Length	**In**	8.15	10.23	10.58	11.37	12.00	13.00
Housing Weight	**lbs**	130	79	168	180	190	206

NEMA Design C, 5 Horsepower, 4-Pole, Enclosed Frame Motor

Figure ES.3.3 presents the relationship between the MSP and full-load efficiency for the 5 horsepower, NEMA Design C, 4-pole enclosed polyphase motor analyzed. DOE purchased one NEMA Design C electric motor for a tear-down analysis. The remaining three CSLs were based on software modeled motors. To achieve higher efficiency levels, the software modeling expert used various combinations of higher grade electrical steel, increased slot fill, increased stack length, changed from aluminum to copper die-cast conductors in the rotors. Figure ES.3.4 shows the efficiency versus MSP curve for the 5 horsepower NEMA Design C electric motor CSLs.

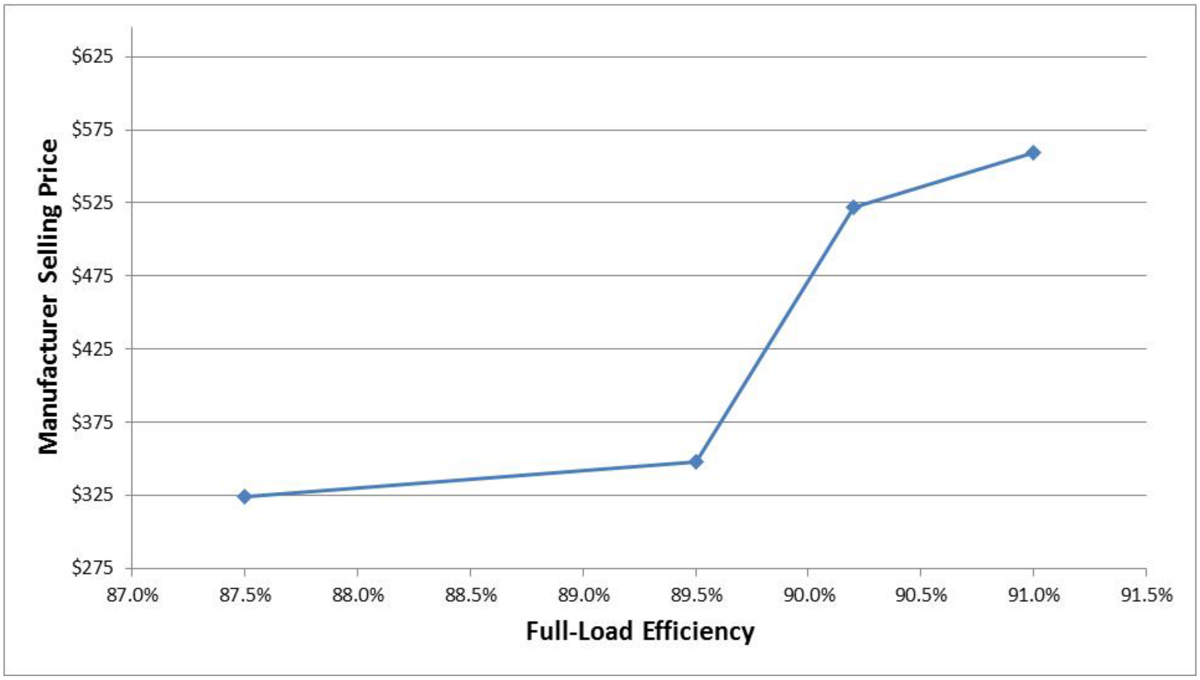

Figure ES.3.4 NEMA Design C, 5 Horsepower, 4-Pole, Enclosed Frame Motor Engineering Analysis Curve

Table ES.3.11 presents the same engineering analysis results in a tabular form, including the nominal full-load efficiency values and the MSPs. Moving from CSL 0 to CSL 2, DOE found that the nominal full-load efficiency would increase 2.7 percentage points over the baseline CSL 0 which represents a 24 percent reduction in motor losses. The increase in MSP to move from CSL 0 to CSL 2 is $198, or about a 61 percent increase in MSP over CSL 0. To increase from CSL 2 to CSL 3 would result in a 10 percent reduction in motor losses and a 7 percent increase in MSP.

Table ES.3.11 Efficiency and Manufacturer Selling Price Data for the NEMA Design C 5 Horsepower Motor

CSL	Nominal Full-Load Efficiency (%)	MSP ($)
0	87.5	324
1	89.5	348
2	90.2	522
3	91.0	559

Table ES.3.12 presents some of the design and performance specifications associated with the four Design C 5 horsepower motors presented in Table ES.3.11.

Table ES.3.12 NEMA Design C 5 Horsepower, 4-Pole, Enclosed Frame Motor Characteristics

Parameter	Units	CSL 0	CSL 1	CSL 2	CSL 3
Efficiency	**%**	87.5	89.5	90.2	91.0
Line Voltage	**V**	460	460	460	460
Full Load Speed	**RPM**	1,750	1,762	1,767	1,776
Full Load Torque	**lb-ft**	15	14.9	14.9	14.8
Current	**A**	7.1	8.4	7.1	6.5
Steel	**-**	M47	M36	M36	M36
Rotor Conductor Material	**-**	Aluminum	Aluminum	Aluminum	Copper
Approximate Slot Fill	**%**	67.9	79.9	83.9	82.9
Stator Wire Gauge	**AWG**	18	18	18	18
Stator Copper Weight	**lbs**	10	9.9	15	12.8
Rotor Conductor Weight	**lbs**	2.2	2.0	2.4	7.8
Stack Length	**in**	4.75	4.25	5.32	5.32
Frame Weight	**lbs**	12	11	14	14

NEMA Design C, 50 Horsepower, 4-Pole, Enclosed Frame Motor

Figure ES.3.5 presents the relationship between the MSP and full-load efficiency for the 5 horsepower, NEMA Design C, 4-pole enclosed polyphase motor analyzed. DOE purchased only one NEMA Design C electric motor for tear-down analysis. The remaining three CSLs were based on software modeled motors. To achieve higher efficiency levels, the software modeling expert used various combinations of higher grade electrical steel, increased slot fill, increased stack length, and copper rotors. Figure ES.3.5 shows the efficiency versus MSP curve for the 50 horsepower NEMA Design C electric motor CSLs.

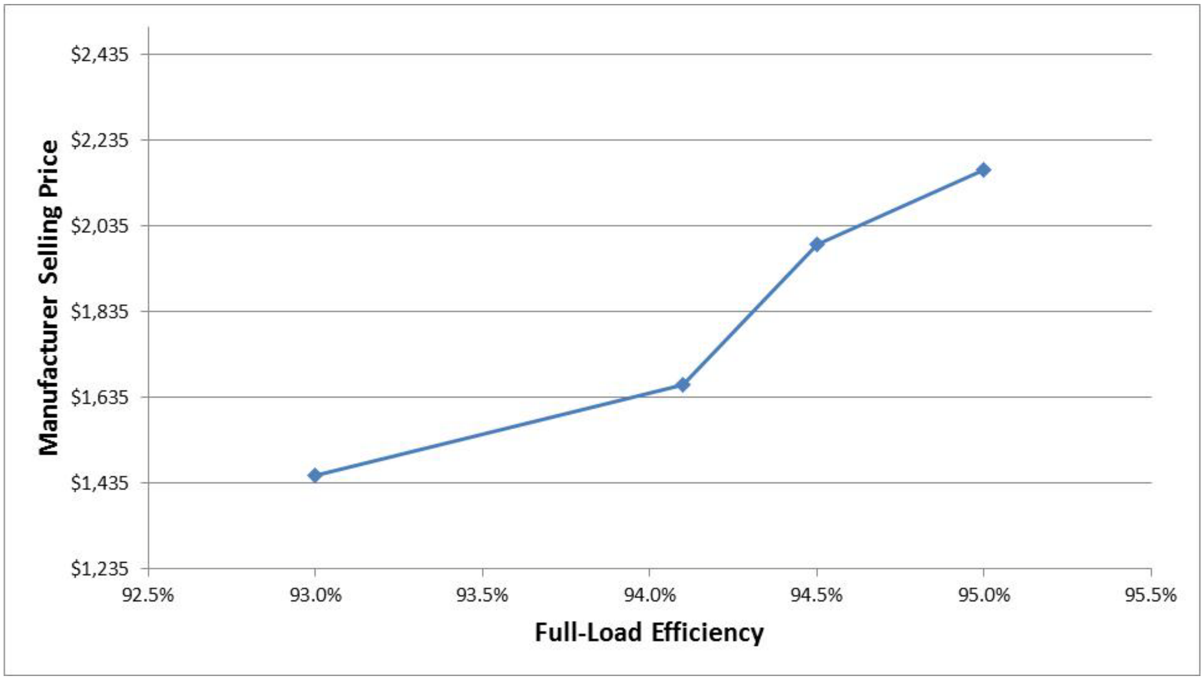

Figure ES.3.5 NEMA Design C, 50 Horsepower, 4-Pole, Enclosed Frame Motor Engineering Analysis Curve

Table ES.3.13 presents the same engineering analysis results in a tabular form, including the nominal full-load efficiency values and the MSPs. Moving from CSL 0 to CSL 2, DOE found that the nominal full-load efficiency would increase 1.5 nominal percentage points over the baseline, CSL 0, which represents about a 23 percent reduction in motor losses. The increase in MSP to move from CSL 0 to CSL 2 is $540, or about a 37 percent increase in MSP over CSL 0. To increase from CSL 2 to CSL 3, a 10 percent reduction in motor losses, results in an 8.8 percent increase in MSP.

Table ES.3.13 Efficiency and Manufacturer Selling Price Data for the NEMA Design C 50 Horsepower Motor

CSL	Nominal Full-Load Efficiency (%)	MSP ($)
0	93.0	1,452
1	94.1	1,664
2	94.5	1,992
3	95.0	2,168

Table ES.3.14 presents some of the design and performance specifications associated with the four 50 horsepower electric motor designs presented in Table ES.3.13.

Table ES.3.14 NEMA Design C 50 Horsepower, 4-Pole, Enclosed Frame Motor Characteristics

Parameter	Units	CSL 0	CSL 1	CSL 2	CSL 3
Efficiency	**%**	93.0	94.1	94.5	95.0
Line Voltage	**V**	460	460	460	460
Full Load Speed	**RPM**	1,770	1,775	1,775	1,782
Full Load Torque	**lb-ft**	148	148	148	147.3
Current	**A**	59.4	63.9	63.7	61.3
Steel	**-**	M47	M36	M36	M19
Rotor Conductor Material	**-**	Aluminum	Aluminum	Aluminum	Copper
Approximate Slot Fill	**%**	79.6	74.8	85.3	81.3
Stator Wire Gauge	**AWG**	17	17	17	17
Stator Copper Weight	**lbs**	66	78	90	85
Rotor Conductor Weight	**lbs**	16.5	11	11	36.6
Stack Length	**In**	8.67	9.55	9.55	9.55
Frame Weight	**lbs**	125	138	138	138

ES.3.4 Markups Analysis

The markups analysis (chapter 6 of the preliminary TSD) develops appropriate markups in the distribution chain to convert the estimates of manufacturer cost derived in the engineering analysis to installed prices for medium electric motors. The engineering analysis (chapter 5 of the preliminary TSD) identifies eight representative units and develops the MSP for each. The eight representative units are evaluated in the LCC analysis (chapter 8 of the preliminary TSD). DOE derived a set of prices for each representative unit by applying markups to the MSP. Those markups represent all the costs associated with bringing a manufactured motor into service as an installed piece of electrical equipment at a customer's site.

For medium electric motors (those built in a three-digit frame number series), DOE defined six distribution channels and estimated their respective shares of shipments. The six channels are:

(1) from manufacturers to original equipment manufacturers (OEMs) and then to end-users (50 percent of shipments);
(2) from manufacturers to distributors and then to end-users (24 percent of shipments);
(3) from manufacturers to distributors to OEMs and then to end-users (23 percent of shipments);
(4) from manufacturers to end-users through contractors (less than 1 percent of shipments);
(5) from manufacturers to distributors to contractors and then to end-users (less than 1 percent of shipments); and
(6) directly to end-users (less than 2 percent of shipments).

Table ES.3.15 summarizes the markups at each stage in the distribution channel and the overall baseline and incremental markups, as well as sales taxes, for each of the primary channels (see items 1 through 3 above).

Table ES.3.15 Summary of Markups for the Three Primary Distribution Channels for Medium Electric Motors

Markup	OEM to End-User (50%)		Distributor to End-User (24%)		Distributor to OEM to End-User (23 %)	
	Baseline	**Incremental**	**Baseline**	**Incremental**	**Baseline**	**Incremental**
Distributor	-	-	1.35	1.20	1.35	1.20
OEM	1.44	1.39	-	-	1.44	1.39
Contractor/Installer	-	-	-	-	-	-
Sales Tax	1.0712	1.0712	1.0712	1.0712	1.0712	1.0712
Overall	1.54	1.49	1.45	1.29	2.08	1.79

Weighting the markups in all six channels by each channel's share of shipments yields an average overall baseline markup of 1.63 and an overall incremental markup of 1.50. DOE used those markups for each equipment class. Applying the markups, DOE generated end-user motor prices for each efficiency level it considered, assuming that each level represents a new minimum efficiency standard.

ES.3.5 Energy Use Characterization

The energy use characterization (chapter 7 of the preliminary TSD) produces energy use estimates for electric motors. Those estimates enable DOE to evaluate the energy savings from the operation of electric motors at the efficiency levels associated with amended efficiency standards. The energy use characterization provides the basis for developing the energy savings used in the LCC and subsequent analyses.

The energy use by electric motors equals the end-use load plus any energy losses associated with motor operation. Energy use is derived from three components: useful mechanical shaft power, motor losses, and reactive power.[b] Motor losses consist of I^2R (resistance heat) losses, core losses, stray-load losses, and friction and windage losses. For a motor having a given nominal efficiency, the annual energy consumption depends on the motor's annual operating hours and loading, which are determined by the motor's sector (industry, agriculture, and commercial) and application (compressor, fans, pumps, material handling and processing, fire pumps, and others).

DOE developed estimates of motor losses and reactive power at full load and part-load for various nominal efficiency levels based on estimates of the specific motor designs that it

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[b] In an alternating current power system, the reactive power is the root mean square (RMS) voltage multiplied by the RMS current, multiplied by the sine of the phase difference between the voltage and the current. Reactive power occurs when the inductance or capacitance of the load shifts the phase of the voltage relative to the phase of the current. Although reactive power does not itself consume energy, it can increase losses and costs for the electricity distribution system. Motors tend to create reactive power because the windings in the motor coils have high inductance.

developed in the engineering analysis. DOE then characterized the energy use of motors within horsepower ranges according to the end-use sector and application. Motor distribution across sectors varied depending on a motor's horsepower range. Motor distribution across applications varied depending on the motor's horsepower range and equipment class group.

Table ES.3.16 shows the results of the energy use analysis for the eight representative units at each considered energy efficiency level. Results are given for baseline units (CSL 0) and the additional candidate standard levels (CSLs) being considered. Chapter 7 provides greater detail regarding the methods, data, and assumptions used for the energy use analysis.

Table ES.3.16 Average Annual Energy Consumption by Efficiency Level for Representative Units

Representative Unit	Description	*kilowatt-hours per year*					
		CSL 0	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**	**CSL 5**
1	Design B, T-frame, 5 hp, 4 poles, enclosed	10,448	9,869	9,691	9,616	9,567	9,487
2	Design B, T-frame, 30 hp, 4 poles, enclosed	57,642	55,912	55,021	54,492	54,326	-
3	Design B, T-frame, 75 hp, 4 poles, enclosed	204,834	202,540	198,496	197,697	197,194	196,604
4	Design C, T-frame, 5 hp, 4 poles, enclosed	9,987	9,808	9,738	9,630	-	-
5	Design C, T-frame, 50 hp, 4 poles, enclosed	89,523	88,507	88,119	87,444	-	-
6	Fire pump, 5 hp, 4 poles, enclosed	19.6	19.2	19.1	19.0	18.8	-
7	Fire pump, 30 hp, 4 poles, enclosed	1,601	1,577	1,562	1,558	-	-
8	Fire pump, 75 hp, 4 poles, enclosed	97,791	95,934	95,554	95,313	95,033	-

ES.3.6 Life-Cycle Cost and Payback Period Analysis

New and amended equipment standards result in changes in customer operating expenses (usually a decrease) and changes in initial customer price (usually an increase). DOE performed the LCC analysis to evaluate the net effect of new and amended standards on customers based on the cost-efficiency relationship derived from the engineering analysis, as well as the energy costs derived from the energy use characterization. Inputs to the LCC calculation include the installed cost to the customer (purchase price plus installation cost), operating costs (primarily energy expenses), expected lifetime of the equipment, and discount rate.

Because the installed cost of equipment typically increases while operating costs typically decrease in response to new or amended standards, there is a period when the net operating-cost benefit (in dollars) since the time of purchase of the more efficient equipment equals the incremental first cost of purchasing the higher efficiency unit. The length of time required for equipment to reach this cost-equivalence point is known as the PBP.

DOE conducted the LCC and PBP analysis using Monte Carlo simulation methods and probability distributions to model both the uncertainty and variability in the inputs. Inputs to the LCC and PBP analysis are:

- motor application and sector
- annual energy use,
- electricity prices and price trends,
- operating hours,
- motor lifetime,
- motor efficiency, and
- a discount rate.

These variables, and the interactions among them, are discussed in the following paragraphs.

DOE characterized a set of end-use applications for electric motors that determine motor use profiles. In each Monte Carlo simulation, one application is identified by sampling a distribution of applications for each equipment class. The selected application determines the number of operating hours per year as well as the motor loading (i.e. output power as a percentage of rated power). DOE used the operating hours and the motor loading for each application to estimate motor energy use.

For electricity prices, DOE derived sector-specific average electricity prices for four census regions (Northeast, Midwest, South, and West) using data from the Energy Information Administration (EIA Form 861). For each sector, DOE assigned electricity prices using a Monte Carlo approach that incorporated weightings based on the estimated number of motors in each region. The regional quantities were derived based on indicators specific to each sector (e.g., for industry, the value of shipments by census region from the Manufacturing Energy Consumption Survey). To estimate future trends in energy prices, DOE used projections from the EIA's *Annual Energy Outlook 2011* (*AEO 2011*).

Because of the wide range of applications and motor use characteristics considered in the LCC and PBP analysis, the range of annual energy use is quite broad. Although the annual energy use and/or energy pricing are generally known for a given application, the variability across all applications contributes to the range of LCCs and PBPs calculated for any particular CSL. There is also an energy use and/or energy pricing distribution between the sectors (industry, agriculture, and commercial) associated with each application. The sector to which an application belongs determines the energy price and discount rate DOE used in each simulation performed for calculating the LCC.

DOE estimated the mechanical lifetime of motors in hours (i.e., the total number of hours a motor operates throughout its lifetime, including repairs) depending on its horsepower (hp) size. DOE then developed Weibull distributions of mechanical lifetimes. (Weibull distributions are statistical models used to predict the likelihood of failure over time.) The lifetime in years for a sampled motor was calculated by dividing the sampled mechanical lifetime by the sampled annual operating hours of the motor. This model produces a negative correlation between annual hours of operation and motor lifetime: motors operated many hours per year are likely to be retired sooner than motors that are used for only a few hundred hours per year. DOE considered that motors of less than 75 hp are most likely to be embedded in another piece of equipment (i.e., an application). For such applications DOE developed Weibull distributions of application lifetimes expressed in years, then compared the sampled mechanical lifetime (in years) with the sampled application lifetime. DOE assumed that the motor would be retired at the younger of the two ages.

DOE made several assumptions regarding motor repair based on stakeholder inputs and on information found in the literature. First, DOE assumed that NEMA Design A, B and C medium electric motors are repaired on average after 32,000 hours of operation[c],and that repair costs vary depending on motor size, configuration, and efficiency. Second, DOE assumed that one-third of repairs are performed competently and according to recommended practice as defined by the Electrical Apparatus Service Association[d] and therefore do not adversely affect the efficiency of the motor (i.e., there is no degradation of efficiency after repair). Third, DOE assumed that the remaining two-thirds of repairs are not performed in a similar manner and result in a slight decrease in efficiency. Finally, DOE assumed the efficiency drops by 1 percent in the case of motors of less than 40 hp, and by 0.5 percent in the case of larger motors.

For each representative unit, DOE developed a projection of base case (no amended standards) efficiency distribution in 2015. DOE based the projection on the percentage of models at different levels using recent manufacturer catalogs. Applying the base case distribution of equipment efficiencies for each representative unit, DOE randomly assigned an equipment efficiency to each unit based on the market share. If a motor was assigned an equipment efficiency greater than or equal to the efficiency of the CSL under consideration, the LCC calculation would show that the motor unit would not be affected by that standard level.

ES.3.6.1 Results of Life-Cycle Cost and Payback Period Analysis

Table ES.3.17 describes the eight representative units that DOE analyzed. The engineering analysis examined units 1 through 5, but did not directly analyze fire pump electric motors. Instead, the engineering outputs for representative units 1, 2, and 3 were assumed to also be valid to characterize representative units 6, 7, and 8.

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[c] 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.

[d] Good practice in motor repair is defined in the joint EASA AEMT study at http://www.easa.com/sites/default/files/rwstdy1203.pdf

Table ES.3.17 Representative Units for Preliminary Analysis

Representative Unit	Equipment Class Group	Specifications	Horsepower
1 2 3	NEMA Designs A & B	Design B, T-frame, enclosed, 4-pole	5 30 75
4 5	NEMA Design C	Design C, T-frame, enclosed, 4-pole	5 50
6 7 8	Fire Pump	Uses same engineering outputs as units 1, 2, and 3	5 30 75

Table ES.3.18 through Table ES.3.25 present key findings from the LCC and PBP analysis performed for this preliminary TSD. Most of the values in the tables are average or median values, although the tables also show the percentage of end-users expected to experience a net cost (negative LCC savings) or net benefit (positive LCC savings) at each CSL. The average LCC savings are calculated relative to a base case efficiency distribution. Chapter 8 of the preliminary TSD presents distributions of LCC and PBP results for each representative unit analyzed.

For representative unit 1 (Table ES.3.18), the highest CSL that provides positive average LCC savings is CSL 3. DOE estimates that 67.8 percent of end-users would experience a net benefit (i.e., LCC decrease) at this CSL and that the increase in average total installed cost (relative to the base case) would be $81, or a 13.9 percent increase, while operating costs decrease by $46, or a 4.6 percent decrease.

Table ES.3.18 Life-Cycle Cost and Payback Period Results for Representative Unit 1: NEMA Design B, T-Frame, 5 Horsepower, 4-Pole, Enclosed Motor

		Life-Cycle Cost			Life-Cycle Cost Savings			Payback Period *years*
						Customers with		
Candidate Standard Level	Efficiency *%*	Average Installed Price *$*	Average Annual Operating Cost *$*	Average LCC *$*	Average Savings *$*	Net Cost *%*	Net Benefit *%*	Median
0	82.5	584	1,006	5,926				
1	87.5	588	969	5,649	16	0.1	5.8	0.1
2	89.5	651	963	5,631	25	18.9	26.4	5.1
3	90.2	665	960	5,608	45	20.5	67.8	4.7
4	91.0	909	960	5,831	-169	89.3	6.5	28.2
5	91.7	998	958	5,883	-220	93.3	5.4	26.9

For representative unit 2 (Table ES.3.19), the highest CSL that provides positive average LCC savings is CSL 3. DOE estimates that 86.6 percent of end-users would experience a net benefit (i.e., LCC decrease) at this CSL and that the increase in average total installed cost (relative to the base case) is $718, or a 45.7 percent increase, while operating costs decrease by $234, or a 4.3 percent decrease.

Table ES.3.19 Life-Cycle Cost and Payback Period Results for Representative Unit 2: NEMA Design B, T-Frame, 30 Horsepower, 4-Pole, Enclosed Motor

Candidate Standard Level	Efficiency %	Life-Cycle Cost			Life-Cycle Cost Savings			Payback Period *years*
		Average Installed Price *$*	Average Annual Operating Cost *$*	Average LCC *$*	Average Savings *$*	Customers with Net Cost *%*	Customers with Net Benefit *%*	Median
0	89.5	1,570	5,489	44,182				
1	92.4	1,986	5,358	43,376	45	0.6	4.9	3.5
2	93.6	2,277	5,295	43,035	177	5.7	32.9	5.3
3	94.1	2,288	5,255	42,666	511	4.0	86.6	0.7
4	94.5	3,468	5,249	43,735	-558	87.1	12.9	23.8

For representative unit 3 (Table ES.3.20), the highest CSL that provides positive average LCC savings is CSL 3. DOE estimates that 47.5 percent of end-users would experience a net benefit (i.e., LCC decrease) at this CSL and that the increase in average total installed cost (relative to the base case) is $1,313, or a 37.9 percent increase, while operating costs decrease by $481, or a 2.8 percent decrease.

Table ES.3.20 Life-Cycle Cost and Payback Period Results for Representative Unit 3: NEMA Design B, T-Frame, 75 Horsepower, 4-Pole, Enclosed Motor

Candidate Standard Level	Efficiency %	Life-Cycle Cost			Life-Cycle Cost Savings			Payback Period *years*
		Average Installed Price *$*	Average Annual Operating Cost *$*	Average LCC *$*	Average Savings *$*	Customers with Net Cost *%*	Customers with Net Benefit *%*	Median
0	93.0	3,463	17,168	124,170				
1	94.1	3,831	17,033	123,348	40	0.8	4.5	2.9
2	95.4	4,296	16,733	121,510	663	1.4	32.9	1.5
3	95.8	4,776	16,687	121,590	597	35.1	47.5	6.5
4	96.2	6,044	16,661	122,598	-340	66.9	25.9	15.5
5	96.5	6,640	16,631	122,905	-639	73.6	23.7	16.0

For representative unit 4 (Table ES.3.21), the highest CSL that provides positive average LCC savings is CSL 1. DOE estimates that 59.9 percent of end-users would experience a net benefit (i.e., LCC decrease) at this CSL and that the increase in average total installed cost (relative to the base case) is $44, or a 7.5 percent increase, while operating costs decrease by $10, or a 1.0 percent decrease.

Table ES.3.21 Life-Cycle Cost and Payback Period Results for Representative Unit 4: NEMA Design C, T-Frame, 5 Horsepower, 4-Pole, Enclosed Motor

Candidate Standard Level	Efficiency *%*	Life-Cycle Cost			Life-Cycle Cost Savings			Payback Period *years*
		Average Installed Price *$*	Average Annual Operating Cost *$*	Average LCC *$*	Average Savings *$*	Customers with Net Cost *%*	Customers with Net Benefit *%*	Median
0	87.5	583	984	5,807				
1	89.5	627	974	5,771	34	32.3	59.9	4.6
2	90.2	903	971	6,007	-203	97.8	2.2	25.0
3	91.0	961	966	6,011	-207	95.6	4.4	20.2

For representative unit 5 (Table ES.3.22), the highest CSL that provides positive average LCC savings is CSL 3. DOE estimates that 57.8 percent of end-users would experience a net benefit (i.e., LCC decrease) at this CSL and that the increase in average total installed cost (relative to the base case) is $1164, or a 41.8 percent increase, while operating costs decrease by $150, or a 1.8 percent decrease.

Table ES.3.22 Life-Cycle Cost and Payback Period Results for Representative Unit 5: NEMA Design C, T-Frame, 50 Horsepower, 4-Pole, Enclosed Motor

Candidate Standard Level	Efficiency *%*	Life-Cycle Cost			Life-Cycle Cost Savings			Payback Period *years*
		Average Installed Price *$*	Average Annual Operating Cost *$*	Average LCC *$*	Average Savings *$*	Customers with Net Cost *%*	Customers with Net Benefit *%*	Median
0	93.0	2,786	8,459	69,419				
1	94.1	3,173	8,383	69,098	236	18.3	55.6	5.9
2	94.5	3,673	8,360	69,329	5	59.6	40.4	12.7
3	95.0	3,950	8,309	69,104	229	42.3	57.8	9.8

For representative unit 6 (Table ES.3.23), all CSLs other than the baseline result in negative average LCC savings.

Table ES.3.23 Life-Cycle Cost and Payback Period Results for Representative Unit 6: Fire Pump, NEMA Design B, T-Frame, 5 Horsepower, 4-Pole, Enclosed Motor

Candidate Standard Level	Efficiency %	Life-Cycle Cost			Life-Cycle Cost Savings			Payback Period *years*
		Average Installed Price *$*	Average Annual Operating Cost *$*	Average LCC *$*	Average Savings *$*	Customers with Net Cost *%*	Customers with Net Benefit *%*	Median
0	87.5	588	106	632				
1	89.5	651	115	697	-62	95.1	0.0	NA
2	90.2	665	119	706	-70	99.9	0.1	NA
3	91.0	909	124	949	-314	100.0	0.0	NA
4	91.7	998	128	1,038	-403	100.0	0.0	NA

For representative unit 7 (Table ES.3.24), all CSLs other than the baseline result in negative average LCC savings.

Table ES.3.24 Life-Cycle Cost and Payback Period Results for Representative Unit 7: Fire Pump, NEMA Design B, T-Frame, 30 Horsepower, 4-Pole, Enclosed Motor

Candidate Standard Level	Efficiency %	Life-Cycle Cost			Life-Cycle Cost Savings			Payback Period *years*
		Average Installed Price *$*	Average Annual Operating Cost *$*	Average LCC *$*	Average Savings *$*	Customers with Net Cost *%*	Customers with Net Benefit *%*	Median
0	92.4	1,986	347	3,869				
1	93.6	2,277	363	4,131	-213	78.8	2.5	104.9
2	94.1	2,288	371	4,124	-207	78.7	8.1	79.2
3	94.5	3,468	380	5,295	-1,378	100.0	0.0	433.6

For representative unit 8 (Table ES.3.25), the highest CSL that provides positive average LCC savings is CSL 3. DOE estimates that 27.0 percent of end-users would experience a net benefit (i.e., LCC decrease) at this CSL and that the increase in average total installed cost (relative to the base case) is 2,213, or a 57.8 percent increase, while operating costs decrease by $126, or a 1.6 percent decrease.

Table ES.3.25 Life-Cycle Cost and Payback Period Results for Representative Unit 8: Fire Pump, NEMA Design B, T-Frame, 75 Horsepower, 4-Pole, Enclosed Motor

Candidate Standard Level	Efficiency %	Life-Cycle Cost			Life-Cycle Cost Savings			Payback Period *years*
		Average Installed Price *$*	Average Annual Operating Cost *$*	Average LCC *$*	Average Savings *$*	Customers with Net Cost *%*	Customers with Net Benefit *%*	Median
0	94.1	3,831	8,050	110,032				
1	95.4	4,296	7,937	108,445	1,274	55.4	25.3	1.1
2	95.8	4,776	7,927	108,544	1,193	56.7	26.0	1.9
3	96.2	6,044	7,924	109,522	215	73.0	27.0	4.5
4	96.5	6,640	7,920	109,826	-89	72.0	28.0	5.3

Chapter 8 of the preliminary TSD provides more details on the methods, data, and assumptions used for the LCC and PBP analyses

ES.3.7 Shipments Analysis

An important component of any estimate of future impacts from energy efficiency standards is equipment shipments (chapter 9). DOE uses projections of shipments for the base case and each potential standards case as inputs to the calculation of national energy savings (NES).

DOE used motor shipment data from multiple sources[e] to develop a set of shipment projections for all motors by horsepower covered by the rulemaking. The shipments represent the sum of U.S. production and imports minus exports and include motors imported as part of larger equipment. DOE then used estimates of market distributions to redistribute the shipments across pole configurations and enclosures to provide shipment values for each electric motor equipment class and sector.

DOE's shipments projection assumes that motor sales are driven by machinery production growth for equipment including motors. DOE assumed that growth rates for motor shipments correlate to growth rates in fixed investment in equipment and structures[f] including motors, as provided by the U.S. Bureau of Economic Analysis's (BEA)[g]. This correlation was developed based on historical data on growth rates for motor shipments and fixed investment

[e] DOE based its shipments estimates on the following sources of data: market research report (IMS Research (February 2012), The World Market for Low Voltage Motors, 2012 Edition, Austin), stakeholder inputs, and responses to the Request for Information (RFI) published in the Federal Register (76 FR 17577 (March 30, 2011)).
[f] Heating, ventilation, and air conditioning (HVAC) equipment which incorporates motors is typically included in "structures" and not in equipment.
[g] Bureau of Economic Analysis (March 01, 2012), Private *Fixed Investment in Equipment and Software and structure by Type*. http://www.bea.gov/iTable/iTable.cfm?ReqID=12&step=1

data. Additional data on “real gross domestic product” (GDP) from *AEO2011* for 2011–2035 was used to project fixed investments in the selected equipment and structures.

Table ES.3.26 presents DOE’s estimate of projected shipments of electric motors following an AEO reference growth case. Additional detail on the shipments analysis, as well as alternate AEO growth cases can be found in chapter 9 of the preliminary TSD.

Table ES.3.26 Annual and Cumulative Shipments Projection for Electric Motors (AEO reference case)

Equipment Class Group	Annual Shipments *thousands*				
	2015	**2025**	**2035**	**2044**	**Cumulative 2015–2044**
Designs A & B	5,072	7,254	9,958	13,005	256,846
Design C	10	15	20	26	515
Fire Pump	6	9	12	16	309
Total*	5,089	7,278	9,990	13,047	257,671

*Total may not precisely match the sum of all numbers in the column due to rounding.

Chapter 9 of the preliminary TSD provides more details on the methods, data, and assumptions used for the shipments analysis.

ES.3.8 National Impact Analysis

The national impact analysis (NIA) quantifies the following national impacts from CSLs: (1) NES, (2) monetary value of the energy savings attributable to new or amended standards, (3) increased total installed costs of the considered equipment due to new or amended standards, and (4) NPV of energy savings (difference between value of energy savings and increased total installed costs). DOE prepared a spreadsheet model to project energy savings and national customer economic costs and savings resulting from potential new standards.

The cumulative NES and NPV are calculated by equipment class. Results are calculated by sector for each equipment class. These results are then aggregated across sectors using weighted averages. DOE used weighted average operating hours and loading data across motor applications in each sector, and assigned a range in lifetime data by horsepower based on usage data from the energy use characterization (chapter 7).

For each equipment class that was not directly analyzed in the engineering analysis and the LCC, DOE specified CSLs using scaled, full-load, nominal efficiency data from the engineering analysis. Adjustment factors were derived from the engineering analysis to estimate part-load nominal efficiencies. Further, relationships were developed to estimate MSP data for all equipment classes. The relationships were derived from analyzing how listed prices in six manufacturers and distributors catalogs vary depending on horsepower, poles, and enclosures at a given efficiency level. A similar method, based on advertised weights in catalog listings, was used to estimate weights for all equipment classes as a necessary input to shipping costs.

ES.3.8.1 Analysis of National Energy Savings

DOE calculated cumulative NES for motors shipped in the analysis period, 2015-2044 as the difference between the cumulative national energy consumption in the base case (without new or amended energy conservation standards) and under each CSL. In the base case, DOE estimated a distribution of equipment efficiencies for each equipment class and assumed this distribution remained constant throughout the analysis period. In the standards case, DOE used a roll-up scenario to determine the distribution of equipment efficiencies at each CSL.

DOE estimated cumulative energy consumption and savings based on site energy, and then converted those values to primary (source) energy using factors that account for losses in transmission, distribution, and generation of electricity.

DOE estimated energy consumption and savings based on site energy and converted the site energy values to primary (source) energy using factors that account for losses in transmission and distribution and in electricity generation. These site-to-source factors are derived from the National Energy Modeling System (NEMS). DOE also estimated full-fuel-cycle (FFC) energy savings for each CSL. The full-fuel-cycle measure includes the energy consumed in extracting, processing, and transporting primary fuels.

Table ES.3.27 summarizes results of the NES for each of the three equipment class groups by horsepower range. NES results are given in quadrillion British thermal units (quads).

Table ES.3.27 Summary of Cumulative National Energy Savings in Quads (2015-2044)

Motor Size *hp*	All	1-5	6-20	21-50	51-100	101-200	201-500
Designs A & B							
CSL 1	0.972	0.270	0.284	0.161	0.108	0.078	0.071
CSL 2	4.414	0.954	1.211	0.668	0.527	0.410	0.644
CSL 3	7.527	1.509	1.980	1.179	0.937	0.831	1.090
CSL 4	10.836	2.123	2.855	1.704	1.378	1.265	1.511
CSL 5	13.005	2.701	3.201	1.704	1.789	1.680	1.929
Design C							
CSL 1	0.012	0.003	0.004	0.002	0.001	0.001	-
CSL 2	0.018	0.004	0.006	0.003	0.002	0.002	-
CSL 3	0.024	0.006	0.008	0.004	0.003	0.003	-
Fire Pumps							
CSL 1	0.003	0.000	0.000	0.000	0.001	0.001	0.001
CSL 2	0.005	0.000	0.000	0.000	0.002	0.001	0.001
CSL 3	0.006	0.000	0.000	0.000	0.002	0.002	0.002
CSL 4	0.008	0.000	0.000	0.000	0.003	0.002	0.002

ES.3.8.2 Analysis of Consumer Net Present Value

DOE calculated net monetary savings each year as the difference between total savings in operating costs and increases in total equipment costs in the base case and each CSL. DOE calculated savings over the life of the equipment purchased during the analysis period. The NPV is the difference between the present value of operating cost savings and the present value of increased total installed costs. DOE used discount rates of 7 percent and 3 percent to discount future costs and savings to the present.

Table ES.3.28 summarizes NPV results for each of the three equipment class groups by horsepower range.

Table ES.3.28 Net Present Value of Customer Impacts (billion 2011$)

	Discount Rate %	All *hp*	1-5 *hp*	6-21 *hp*	21-50 *hp*	51-100 *hp*	101-200 *hp*	201-500 *hp*
Designs A & B								
CSL 1	3	5.53	1.67	1.78	0.94	0.54	0.35	0.25
	7	2.32	0.73	0.76	0.38	0.22	0.13	0.09
CSL 2	3	18.42	3.57	5.52	2.98	2.27	1.68	2.41
	7	7.07	1.39	2.15	1.13	0.90	0.63	0.87
CSL 3	3	30.19	5.65	8.50	4.91	3.71	3.25	4.16
	7	11.42	2.24	3.25	1.80	1.43	1.20	1.50
CSL 4	3	-6.63	-6.29	-4.67	-1.32	0.57	1.73	3.34
	7	-10.37	-4.47	-4.37	-1.90	-0.50	0.10	0.77
CSL 5	3	-8.63	-8.81	-5.92	-1.32	0.64	2.38	4.40
	7	-12.71	-6.09	-5.26	-1.90	-0.70	0.19	1.05
Design C								
CSL 1	3	0.05	0.01	0.02	0.01	0.00	0.00	-
	7	0.02	0.01	0.01	0.00	0.00	0.00	-
CSL 2	3	0.01	-0.01	0.00	0.01	0.01	0.01	-
	7	-0.01	-0.01	0.00	0.00	0.00	0.00	-
CSL 3	3	0.02	-0.01	0.00	0.01	0.01	0.01	-
	7	-0.01	-0.01	0.00	0.00	0.00	0.00	-
Fire Pumps								
CSL 1	3	-0.02	-0.01	-0.01	0.00	0.00	0.00	0.00
	7	-0.01	0.00	0.00	0.00	0.00	0.00	0.00
CSL 2	3	-0.03	-0.02	-0.01	-0.01	0.00	0.00	0.00
	7	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00
CSL 3	3	-0.10	-0.04	-0.04	-0.02	0.00	0.00	0.00
	7	-0.05	-0.02	-0.02	-0.01	0.00	0.00	0.00
CSL 4	3	-0.11	-0.05	-0.05	-0.02	0.00	0.00	0.00
	7	-0.06	-0.02	-0.02	-0.01	0.00	0.00	0.00

Table ES.3.29 summarizes both NES and NPV results for each of the three equipment class groups.

Table ES.3.29 Cumulative National Energy Savings and Net Present Value Results

Equipment Group and Analysis	Discount Rate %	Candidate Standard Level				
		1	2	3	4	5
Designs A & B						
Cumulative Source Savings 2015–2044 *quads*		0.97	4.41	7.53	10.84	13.00
Net Present Value *billion 2011$*	3	5.53	18.42	30.19	-6.63	-8.63
	7	2.32	7.07	11.42	-10.37	-12.71
Design C						
Cumulative Source Savings 2015–2044 *quads*		0.01	0.02	0.02	-	-
Net Present Value *billion 2011$*	3	0.05	0.01	0.02	-	-
	7	0.02	-0.01	-0.01	-	-
Fire Pumps						
Cumulative Source Savings 2015–2044 *quads*		0.00	0.00	0.01	0.01	-
Net Present Value *billion 2011$*	3	-0.02	-0.03	-0.10	-0.11	-
	7	-0.01	-0.01	-0.05	-0.06	-

Chapter 10 of the preliminary TSD provides more details on the methods, data, and assumptions used for the NIA analyses.

ES.3.9 Preliminary Manufacturer Impact Analysis

The preliminary MIA focuses on manufacturers of electric motors. Potential impacts include financial effects, both quantitative and qualitative, that might result from new energy conservation standards and consequently lead to changes in the manufacturing practices for electric motors. DOE identified these potential impacts through interviews with manufacturers and interested parties, as well as through the gathering of publicly available data on products, methods, and practices used in the electric motors industry.

Next, DOE determined how energy efficiency improvements affect cost, production, and various other manufacturing metrics.

Finally, DOE interviewed manufacturers for feedback. DOE developed a questionnaire and distributed it for use during the interviews. Highlights of the questionnaire and topics of focus include production and product mix, compliance costs, exports, foreign competition and outsourcing, market shares and industry consolidation, and cumulative burden.

Perhaps the most important aspect of the preliminary MIA is the opportunity to identify key manufacturer issues early in the development of new standards. During the series of preliminary interviews with manufacturers, DOE assessed concerns about the potential impact of a regulatory standard for electric motors. In general, manufacturers identified three major issues of concern: (1) capital expenditure to retool in response to the standards, (2) maintaining product availability and consumer-oriented features, and (3) enforcement of the new standards.

ES.3.10 Other Analyses

The remaining chapters of the preliminary TSD address the analyses to be performed for the notice of proposed rulemaking (NOPR).

- The customer subgroup analysis evaluates the effects of potential new or amended energy conservation standards on various subgroups (chapter 11).
- The employment impact analysis examines the effects of potential new or amended energy conservation standards on national employment (chapter 13).
- The utility impact analysis examines impacts of potential new or amended energy conservation standards on the generation capacity of electric utilities (chapter 14).
- The emissions analysis examines the effects of potential new or amended energy conservation standards on various airborne emissions (chapter 15)
- The monetization of emission reduction benefits examines the monetary value of benefits resulting from reduced emissions associated with potential new or amended standards (chapter 16).
- The regulatory impact analysis examines the national impacts of nonregulatory alternatives to mandatory energy conservation standards (chapter 17).

ES.4 ISSUES ON WHICH DOE SEEKS PUBLIC COMMENT

DOE is interested in receiving comments on all aspects of the preliminary analyses described in this TSD. DOE especially invites comments or data to improve DOE's analyses, including information that will respond to the following questions and concerns that were raised during DOE's preliminary interviews with manufacturers and in the preparation of this preliminary TSD.

ES.4.1 Scope of Coverage of Electric Motors

DOE invites comments on the scope of motors covered as part of this analysis. Chapter 2 of this TSD presents a list of general purpose motors without energy conservation standards prescribed under EISA 2007 or DOE regulations. These motors generally bear no electromechanical differences from those general purpose motors that are currently regulated. Because of the close similarity between these two sets of motors, DOE tentatively concludes that these currently unregulated motors can achieve the same standards as equipment class group 1 or equipment class group 2 if manufacturers use similar tooling. Refer to chapter 3 of the preliminary TSD for more information on the motors DOE is considering.

ES.4.2 Screening Analysis

DOE invites comments on the two technology options that were screened out of the analysis: plastic bonded iron powder and amorphous core steels for electric motors. Please refer to section 2.4.1 of chapter 2 of the preliminary TSD.

ES.4.3 Engineering Analysis Methodology

DOE invites comments on the methodology followed for the preliminary TSD, namely use of engineering software to design more efficient versions of the five representative units analyzed. DOE is also interested in comments on the estimated manufacturer markups and labor rates that enable the conversion of input costs to selling prices. Please refer to chapter 5 of the preliminary TSD for more detailed information on material prices and markups used.

ES.4.4 Engineering Analysis Results

DOE invites comments on the findings of the engineering analysis. Specifically, DOE requests comment on the derived MSP for its respective motor rating.

ES.4.5 Motor Distribution Across Sectors

DOE seeks comment on any additional sources of data that could be used to establish the distribution of motors across sectors by horsepower range.

ES.4.6 Motor Distribution Across Applications

DOE seeks comment on any additional sources of data that could be used to establish the sector-specific distribution of motors across applications. In its preliminary analysis, DOE assumed that the share of motors in each application is similar across all sectors and equal to the distribution of motors across applications in the industry sector.

ES.4.7 Data on Operating Hours and Loading

DOE seeks comment on any additional sources of field data on operating hours and loading for motors, that could be used to improve field use characterization in the commercial and agricultural sectors.

ES.4.8 Product Price Determination

DOE derived the product prices cited in this TSD by applying markups to the MSP it determined in the engineering analysis. DOE defined six distribution channels and estimated each one's share of shipments. DOE calculated an average overall baseline markup and an overall incremental markup by weighting the markups in all six channels by each channel's share of shipments. DOE requests stakeholder input regarding any viable alternative approach or source of information that could be used to develop product prices.

ES.4.9 Repair Costs

DOE welcomes comment on the current method used to determine motor repair costs.

ES.4.10 Frequency of Repair

DOE seeks comment on any additional sources for determining the frequency of motor repair depending on equipment class, sector, and application.

ES.4.11 Maintenance Costs

DOE seeks comment on any additional sources of data on motor maintenance costs. Specifically, DOE invites comment on how amended efficiency requirements may affect maintenance costs.

ES.4.12 Installation Costs

For the engineering analysis performed for the NOPR, DOE will consider technology options that could affect a motor's mechanical configuration. DOE invites comment on how changes in motor mechanical configurations that may accompany more efficient motors may affect installation costs.

ES.4.13 Motor Lifetimes

DOE seeks comment on any additional sources of data on motor lifetime that could be used to validate DOE's estimates of motor mechanical lifetime and its method of estimating lifetimes.

ES.4.14 Product Energy Efficiency in the Base Case

For the LCC analysis, DOE analyzed CSLs relative to a base case. This analysis requires estimating the distribution of product efficiencies in the base case (i.e., what customers would purchase in 2015 in the absence of new standards). For the preliminary TSD, the distribution of product efficiencies that DOE estimated in the base case was based on nominal efficiency data collected from six major manufacturer catalogs. DOE seeks comment on the estimated base case distribution of product efficiencies and on any additional sources of data.

ES.4.15 Efficiency Trends

DOE seeks further comment on its decision to use constant efficiencies for the analysis period. Specifically, DOE would like comments on additional sources of data on trends in efficiency improvement.

ES.4.16 Estimated Shipments

DOE seeks comment on any additional sources of data on motor shipments that could be used to validate its shipments model and estimates.

ES.4.17 Purchase Price Elasticity

If the installed cost of electric motors increases, end-users could decide to repair or rewind motors instead of purchasing new ones, thereby reducing purchases of new motors. DOE, however, has found no data that would enable it to estimate the elasticity of electric motor shipments with respect to changes in purchase price. DOE seeks comment on any sources of data that could be used to quantitatively estimate motor price elasticity. DOE also seeks comments on any additional sources of data on the share of motor shipments which are for new installation, and the share of shipments which are for replacement.

ES.4.18 Scaling Methodology for Manufacturer Selling Price

DOE seeks comment on its scaled values for MSPs. In particular, DOE seeks comments on its methodology for scaling MSP data from the representative equipment classes to the remaining equipment classes.

ES.4.19 Scaling Methodology for Motor Weights

DOE seeks comment on the scaled values for motor weights. In particular, DOE seeks comments on its methodology for scaling weight data from the representative equipment classes to the remaining equipment classes.

ES.4.20 Trial Standard Levels

For the NOPR, DOE will develop trial standard levels (TSLs) based on the CSLs selected for electric motors. DOE is considering developing TSLs by equipment class group (i.e., all equipment classes in the same equipment class group would be at the same CSL level within this TSL). Further, DOE is considering several criteria in developing the TSLs, including, but not limited to, minimum LCC, maximum NPV, and "max tech" efficiency. The TSLs may include combinations of CSLs. From the TSLs it develops, DOE will select one as its proposed standard for each equipment class group in the NOPR. DOE invites comment on the criteria it should use as the basis for selecting TSLs.