

PRELIMINARY TSD EXECUTIVE SUMMARY

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ES.1 OVERVIEW OF CURRENT ACTIVITIES

Part A–1 of Title III of the Energy Policy and Conservation Act (EPCA) provides for an energy conservation program for certain commercial and industrial equipment. (42 U.S.C. 6311-6317) In particular, section 346(b)(1) of EPCA directs the Secretary of Energy to prescribe, by rule, testing requirements and energy conservation standards for those small electric motors for which the Secretary determines that standards would be technologically feasible and economically justified, and would result in significant energy savings. (42 U.S.C. 6317(b)(1))

This executive summary describes current activities and key results from the preliminary analyses that the Department of Energy (DOE) conducted in consideration of amended energy conservation standards for small 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 these seven factors, 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.

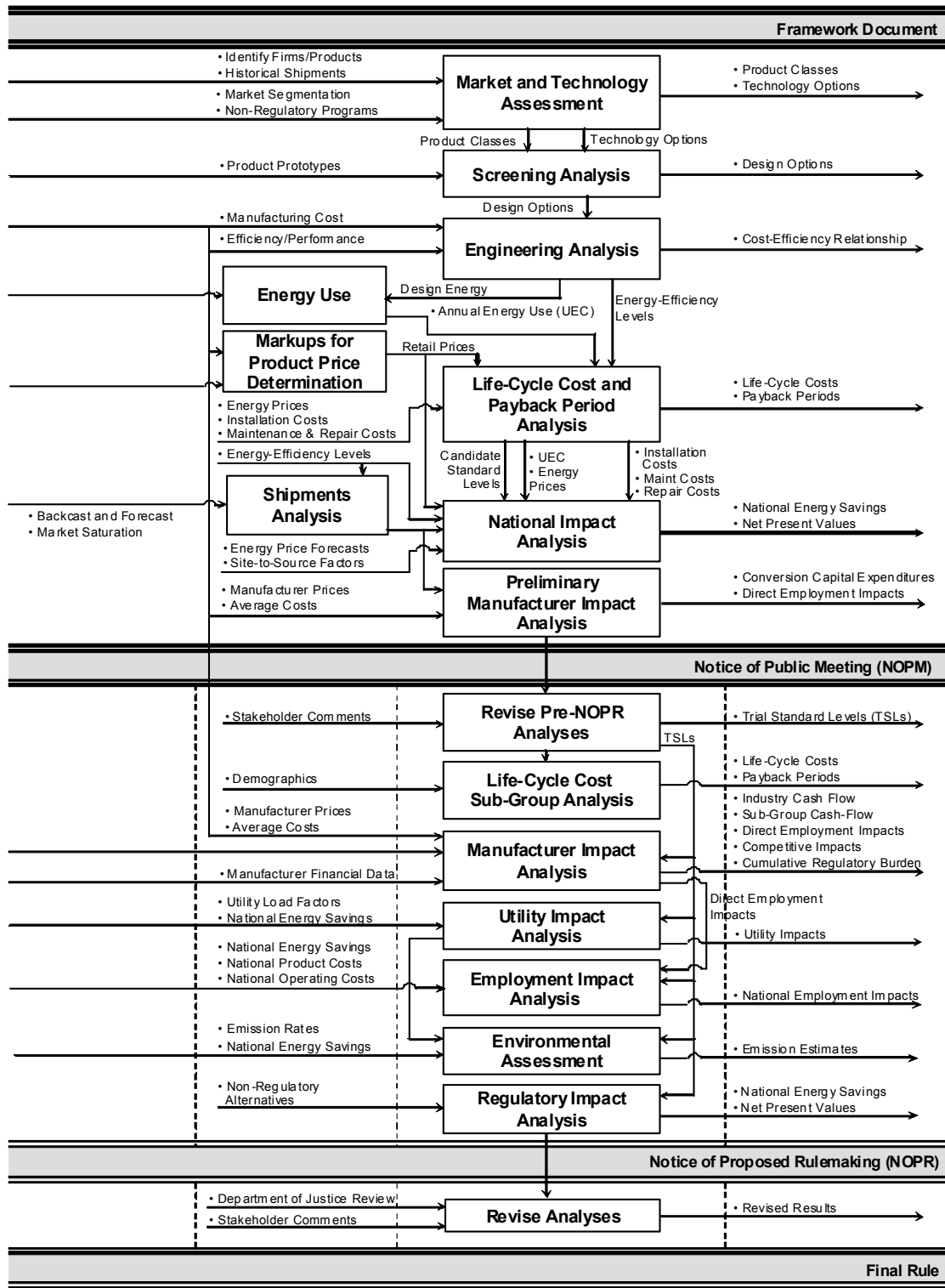


Figure ES.1.1 Flow Diagram of Small Electric Motor Rulemaking Analyses

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 below, 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 (MPC) 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 forecasts 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: A national impact analysis (NIA) that assesses the aggregate impacts at the national level of the NPV of total consumer LCC and national energy savings (NES).

Chapter 11: A life-cycle cost 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: A utility impact analysis that examines impacts of energy conservation standards on the generation capacity of electric utilities.

Chapter 14: An employment impact analysis that examines the effects of energy conservation standards on national employment.

Environmental Assessment Report: An analysis that evaluates the reduced power plant emissions resulting from reduced consumption of electricity.

Regulatory Impact Analysis Report: An 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.

Details on each analysis can be found both in the preliminary TSD chapter 2 and the respective chapter identified in each of the bulleted items above.

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 small electric motors industry in the United States. Industry publications and trade journals, government agencies, and trade organizations provided the bulk of the information, including (1) manufacturers and their market shares, (2) shipments by equipment class,

(3) equipment information, and (4) industry trends. The appropriate sections of the 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 those that DOE believes are technologically feasible for improving equipment efficiency. DOE developed its list of technologically feasible technologies for small 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; and (4) have adverse impacts on health and safety. DOE develops an initial list of efficiency-enhancement options (i.e., technology options) from the technologies 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. In the engineering analysis, DOE uses the efficiency-enhancement options (i.e., technology options) that it did not screen out in the screening analysis to estimate the characteristics and the cost of higher efficiency equipment.

ES.3.3 Engineering Analysis

The engineering analysis (chapter 5) establishes the relationship between the manufacturer selling price and the equipment 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 manufacturer selling price, the cost-efficiency curves for equipment classes analyzed, and the methodology DOE used to scale those results to other equipment classes of small electric motors that were not analyzed.

ES.3.3.1 Equipment Classes Analyzed

Because of the large number of small electric motor equipment classes, DOE did not analyze each one in the engineering analysis. Instead, DOE analyzed three equipment classes, one from each of the representative categories (i.e., polyphase; capacitor-start, induction-run (CSIR); and capacitor-start, capacitor-run (CSCR)). DOE used catalog data, discussions with industry experts, and the Framework Document to select equipment classes to analyze. DOE understands that the equipment classes analyzed are representative of the commercial and industrial small electric motor market and are therefore reasonable selections for the engineering

analysis. After determining the scope of coverage (see preliminary TSD chapter 2 or 3 for discussion on scope of coverage), DOE chose to analyze one polyphase motor, two CSIR motors, and one CSCR motor. The two CSIR motors are of a different frame series, but still represent the same equipment class. The motors presented in Table ES.3.1 are the four motors that DOE analyzed. The left three columns provide the three characteristics of a small electric motor that define its equipment class – namely, motor category, horsepower and number of poles.

Table ES.3.1 Design Characteristics of the Four Baseline Motors Analyzed

Motor Category	Horsepower	Number of Poles	Frame Series
Polyphase	1.00	4	56
CSIR	0.50	4	56
CSIR	0.50	4	48
CSCR	0.75	4	56

ES.3.3.2 Engineering Analysis Results

For each of the four motors presented above, DOE developed five designs using a motor design software tool. These included a baseline design and four more efficient designs above the efficiency of the baseline motor. Then by using a consistent methodology and pricing scheme including material and labor costs and manufacturer’s markups, DOE developed manufacturer selling prices for the baseline and more efficient motor designs. Throughout this section, DOE will refer to these bottoms-up derived and manufacturer marked-up selling prices as “manufacturer selling prices.”

Thus, the engineering analysis results are essentially four manufacturer selling price-versus-efficiency curves that represent the four motors analyzed from the representative equipment classes. The four graphs shown in Figure ES.3.2 through Figure ES.3.5 provide the manufacturer selling price versus efficiency curves and the Table ES.3.2 through Table ES.3.9 present the tabulated results.

In determining the relationship between manufacturing selling price and energy efficiency for small electric motors, DOE estimated the increase in manufacturing selling price associated with technological changes that increase the efficiency of 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.

Polyphase, 1 Horsepower, 4-Pole, 56-Frame Motor

Figure ES.3.2 presents the relationship between the manufacturer selling price and full-load efficiency for the polyphase motor analyzed. DOE developed a maximum technology (max-tech) design using a non-traditional steel type (i.e., Hipercro 50™) that makes the motor considerably more expensive than other designs analyzed.

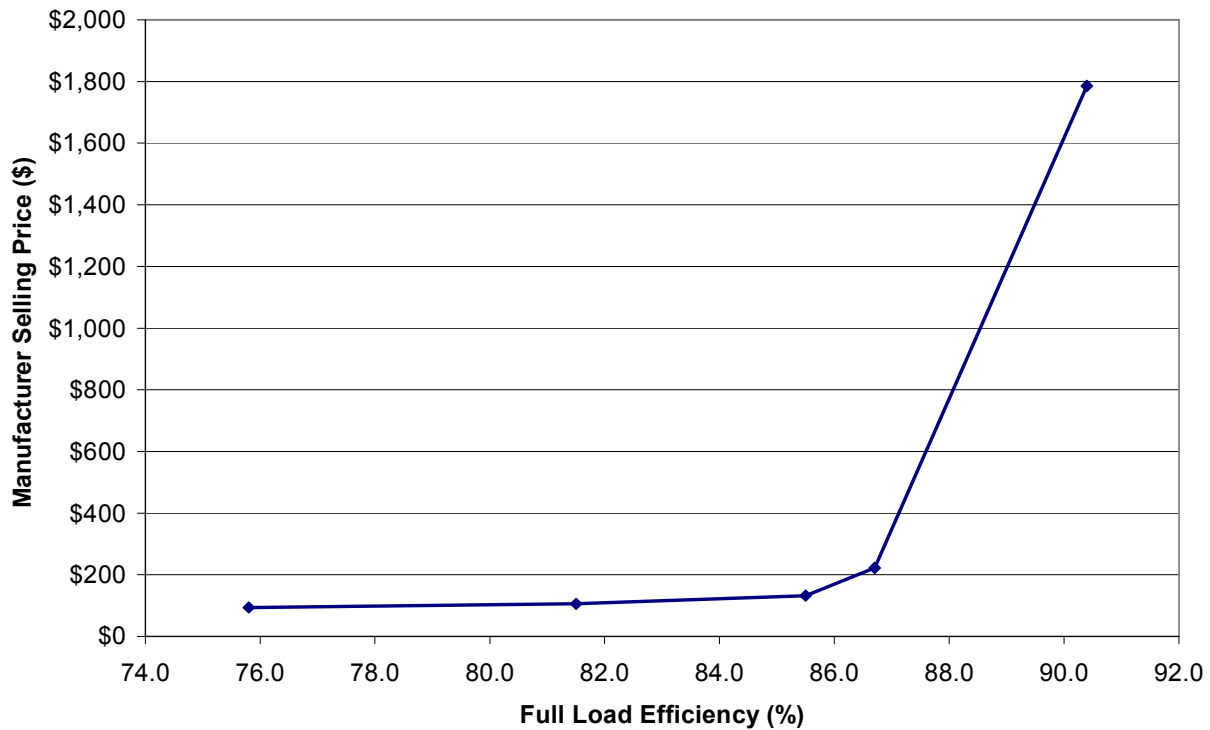


Figure ES.3.2 Polyphase 1 Horsepower, 4-Pole, 56-Frame Motor Engineering Analysis Curve

Table ES.3.2 presents the same engineering analysis results in a tabular form, including the full-load efficiency values and the MSPs. Moving from the baseline motor to the premium plus motor, DOE found that the full-load efficiency would increase 10.9 percentage points, for about a 14-percent improvement over the baseline motor. Raising the efficiency to that level caused the MSP to more than double, increasing from \$93.46 for the baseline model to \$221.35 for the premium plus motor.

Table ES.3.2 Efficiency and Manufacturer Selling Price Data for the Polyphase Motor

Motor Design	Efficiency (%)	Manufacturer Selling Price (\$)
Baseline	75.8	93.46
Energy Efficient	81.5	105.23
Premium	85.5	131.55
Premium Plus	86.7	221.35
Max Tech	90.4	1,785.49

Table ES.3.3 presents some of the design and performance specifications associated with the five polyphase designs presented above. To convey additional information on a few of these designs, DOE prepared appendix 5A to the preliminary TSD, which presents detailed design and

performance specification on one motor design (i.e., the premium motor design) from each of the representative motors analyzed. For the polyphase motor designs prepared, DOE presents detailed design information on the premium motor design, which is 85.5 percent efficient and has a manufacturer’s selling price of \$131.55.

Table ES.3.3 Polyphase, 1 Horsepower, 4-Pole, 56-Frame Motor Designs

Parameter	Units	Baseline	Energy Efficient	Premium	Premium Plus	Max Tech
Efficiency	%	75.8	81.5	85.5	86.7	90.4
Line Voltage	V	230	230	230	230	230
Speed	RPM	1,714	1,703	1,709	1,719	1,729
Torque	oz-ft	49.6	51.2	49.8	51.4	48.3
Current	A	4.5	4.0	4.0	3.9	3.1
Steel		24M56	24M56	24M19	29M15	Hiperco 50 0.006
Rotor Conductor Material		Aluminum	Aluminum	Aluminum	Copper	Copper
Main Wire	AWG	19.0	20.0	19.0	20.5	19.0
Main Wire Weight	lbs	2.530	4.250	5.480	5.850	9.584
Rotor Conductor Weight	lbs	1.069	1.078	1.174	1.900	4.890
Peak Slot Fill	%	32.0	55.0	68.4	74.6	73.9
Locked Rotor Torque	oz-ft	125.0	128.0	125.0	127.0	124.0
Locked Rotor Current	A	18.5	17.5	17.5	18.6	18.2
Stack Length	in	2.75	2.85	3.00	3.00	3.50
Laminations Per Stack	#	110	114	120	215	584
Housing Weight	lbs	6.41	6.50	6.60	6.60	7.56
Slot Liner	in ²	126.186	130.818	137.522	137.522	160.440
Slot Peg	in ²	16.319	16.917	17.795	17.795	20.640

Capacitor-Start, Induction-Run, ½ Horsepower, 4-Pole, 56-Frame Motor

Figure ES.3.3 presents the relationship between the MSP and full-load efficiency for the 56-frame capacitor-start, induction-run motor. The max-tech design incorporates a high-grade premium electromagnetic steel alloy that is much more expensive than the high quality electromagnetic steel alloy used in the premium plus (second most efficient) design.

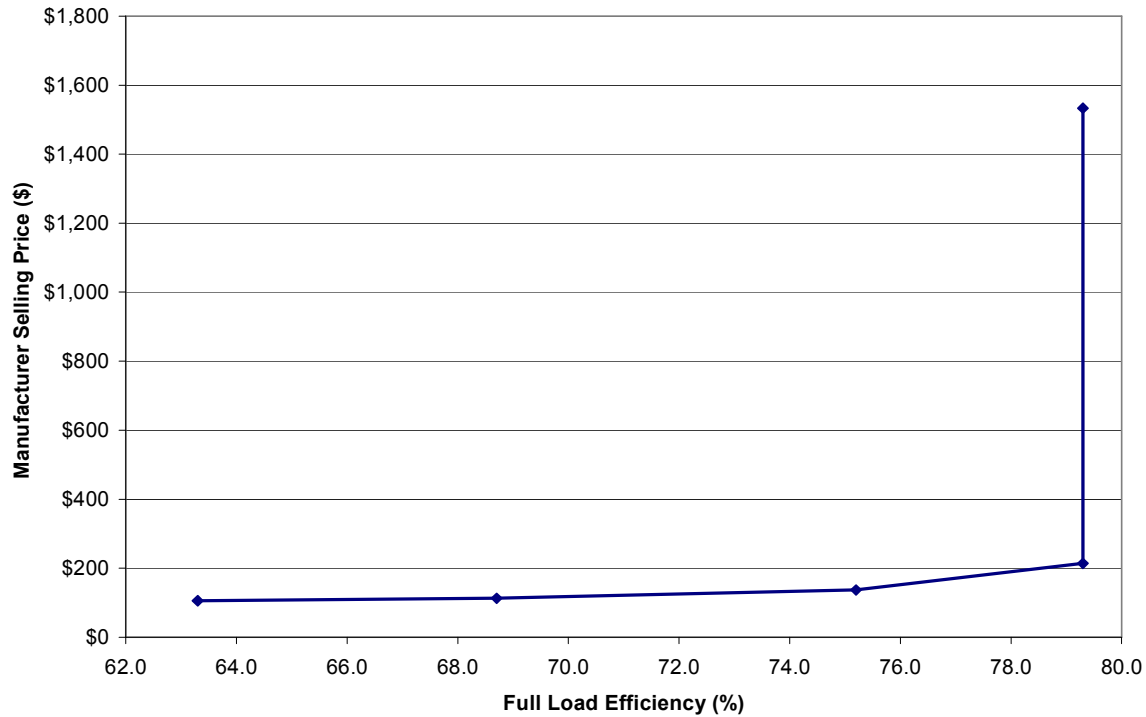


Figure ES.3.3 Capacitor-Start, Induction-Run ½ Horsepower, 4-Pole, 56-Frame Engineering Analysis Curve

Table ES.3.4 presents the same engineering analysis results in a tabular form, including the full-load efficiency values and the MSPs. Moving from the baseline motor to the premium plus motor, DOE found that the full-load efficiency would increase 16 percentage points, for about a 25-percent improvement over the baseline motor. Raising the efficiency to that level caused the MSP to more than double, increasing from \$105.61 for the baseline model to \$213.82 for the premium plus motor.

Table ES.3.4 Efficiency and Manufacturer Selling Price Data for the Capacitor-Start, Induction-Run 56-Frame Motor

Motor Design	Efficiency (%)	Manufacturer Selling Price (\$)
Baseline	63.3	105.61
Energy Efficient	68.7	112.86
Premium	75.2	136.51
Premium Plus	79.3	213.82
Max Tech	79.3	1,532.94

Table ES.3.5 presents some of the design and performance specifications associated with the five CSIR 56-frame designs presented above. DOE also provides additional design detail and performance specifications for the premium motor design in the preliminary TSD, appendix 5A.

Table ES.3.5 Capacitor-Start, Induction-Run, ½ Horsepower, 4-Pole, 56-Frame Motor Designs

Parameter	Units	Baseline	Energy Efficient	Premium	Premium Plus	Max Tech
Efficiency	%	63.3	68.7	75.2	79.3	79.3
Line Voltage	V	115	115	115	115	115
Speed	RPM	1,727	1,727	1,727	1,760	1,760
Torque	oz-ft	24.37	24.44	26.41	24.13	24.13
Current	A	9.17	7.98	8.48	8.18	8.18
Steel		24M56	24M56	24M19	29M15	Hiperco 50 0.006
Rotor Conductor Material		Aluminum	Aluminum	Aluminum	Copper	Copper
Main Wire	AWG	20.5	20	19	19	20
Auxiliary Wire	AWG	20.5	20	19.5	19	19
Main Wire Weight	lbs	2.586	3.063	3.777	3.777	5.117
Auxiliary Wire Weight	lbs	0.955	1.101	1.327	1	1.068
Rotor Conductor Weight	lbs	0.723	1.06	1.09	1.71	2.67
Start Capacitor	µF	300	300	300	450	450
Peak Slot Fill	%	58.82	65.97	74.95	74.12	74.7
Locked Rotor Torque	oz-ft	85	85.2	87.08	90.22	93.78
Locked Rotor Current	A	36.1	34.6	37.5	41.16	38
Stack Length	in	2	2.3	2.6	2.6	3
Laminations Per Stack	#	80	92	104	186	500
Housing Weight	lbs	6.1	6.15	6.3	6.3	7.245
Slot Liner	in ²	91.71	105.56	119.17	119.17	137.3
Slot Peg	in ²	11.86	13.66	15.42	15.42	17.71

Capacitor-Start, Induction-Run, ½ Horsepower, 4-Pole, 48-Frame Motor

Figure ES.3.4 presents the relationship between the MSP and full-load efficiency for the 48-frame capacitor-start, induction-run motor. The max-tech design incorporates a high-grade premium electromagnetic steel alloy that is much more expensive than the high quality electromagnetic steel alloy used in the premium plus (second most efficient) design.

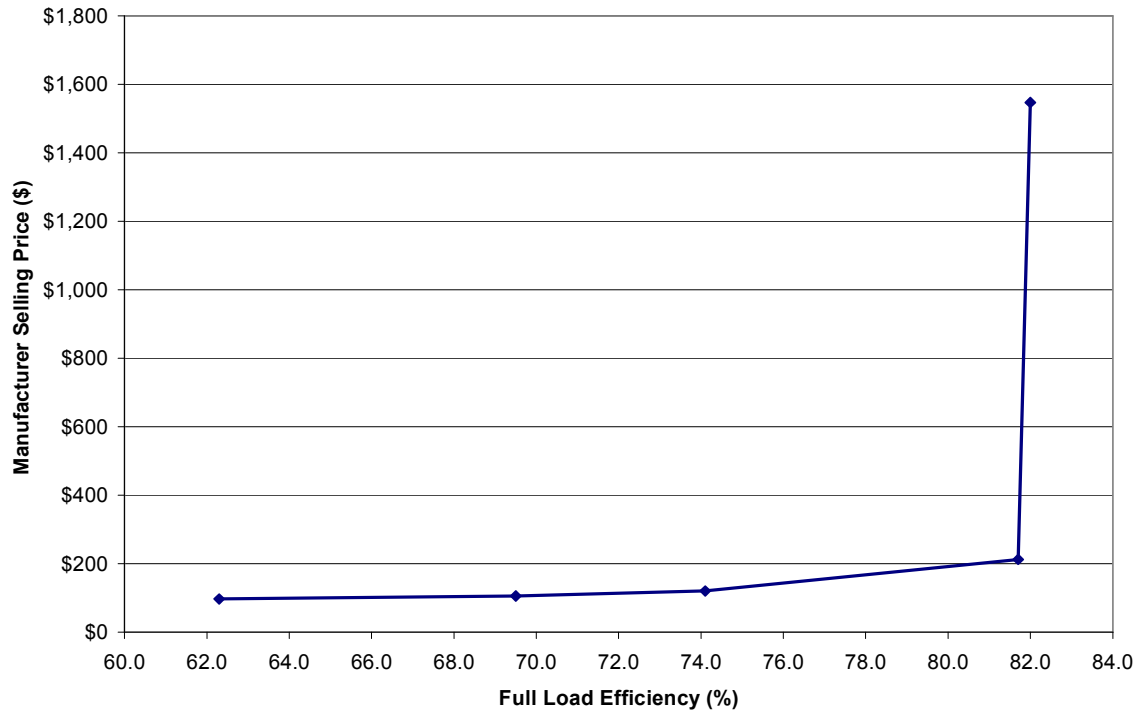


Figure ES.3.4 Capacitor-Start, Induction-Run ½ Horsepower, 4-Pole, 48-Frame Engineering Analysis Curve

Table ES.3.6 presents the same engineering analysis results in a tabular form, including the full-load efficiency values and the MSPs. Moving from the baseline motor to the premium plus motor, DOE found that the full-load efficiency would increase 19.4 percentage points, for about a 31-percent improvement over the baseline motor. Raising the efficiency to that level caused the MSP to more than double, increasing from \$96.97 for the baseline model to \$212.40 for the premium plus motor.

Table ES.3.6 Efficiency and Manufacturer Selling Price Data for Capacitor-Start, Induction-Run 48-Frame Motor

Motor Design	Efficiency (%)	Manufacturer Selling Price (\$)
Baseline	62.3	96.97
Energy Efficient	69.5	105.79
Premium	74.1	120.00
Premium Plus	81.7	212.40
Max Tech	82.0	1,547.11

Table ES.3.7 presents some of the design and performance specifications associated with the five CSIR 48-frame designs presented above. DOE also provides additional design detail and performance specifications for the premium motor design in appendix 5A of the preliminary TSD.

Table ES.3.7 Capacitor-Start, Induction-Run, ½ Horsepower, 4-Pole, 48-Frame Motor Designs

Parameter	Units	Baseline	Energy Efficient	Premium	Premium Plus	Max Tech
Efficiency	%	62.3	69.5	74.1	81.7	82.0
Line Voltage	V	115	115	115	115	115
Speed	RPM	1,737	1,736	1,738	1,765	1,743
Torque	oz-ft	24.2	24.4	24.2	24.2	24.2
Current	A	9.0	8.1	8.1	7.3	6.7
Steel		24M56	24M56	24M19	29M15	Hiperco 50 0.006
Rotor Conductor Material		Aluminum	Aluminum	Aluminum	Copper	Copper
Main Wire	AWG	19.5	20.5	20.5	20.0	20.5
Auxiliary Wire	AWG	20.0	20.0	20.0	21.5	21.5
Main Wire Weight	lbs	1.561	2.591	2.636	3.114	4.498
Auxiliary Wire Weight	lbs	0.916	0.957	0.974	1.155	1.262
Rotor Conductor Weight	lbs	0.645	0.675	0.688	2.392	3.990
Start Capacitor	µF	300	300	300	440	440
Peak Slot Fill	%	49.0	72.2	72.2	74.9	74.6
Locked Rotor Torque	oz-ft	85.3	89.2	90.1	84.1	114.3
Locked Rotor Current	A	35.1	34.3	34.4	45.2	42.2
Stack Length	in	2.65	2.90	3.00	3.40	4.00
Laminations Per Stack	#	106	116	120	243	667
Housing Weight	lbs	4.70	4.90	5.00	5.50	6.65
Slot Liner	in ²	121.440	133.008	137.575	155.920	188.990
Slot Peg	in ²	15.710	17.211	17.802	20.177	24.410

Capacitor-Start, Capacitor-Run, ¾ Horsepower, 4-Pole, 56-Frame Motor

Figure ES.3.5 presents the relationship between the MSP and full-load efficiency for the CSCR motor. The max-tech design incorporates a high-grade premium electromagnetic steel alloy that is much more expensive than the high quality electromagnetic steel alloy used in the premium plus (second most efficient) design.

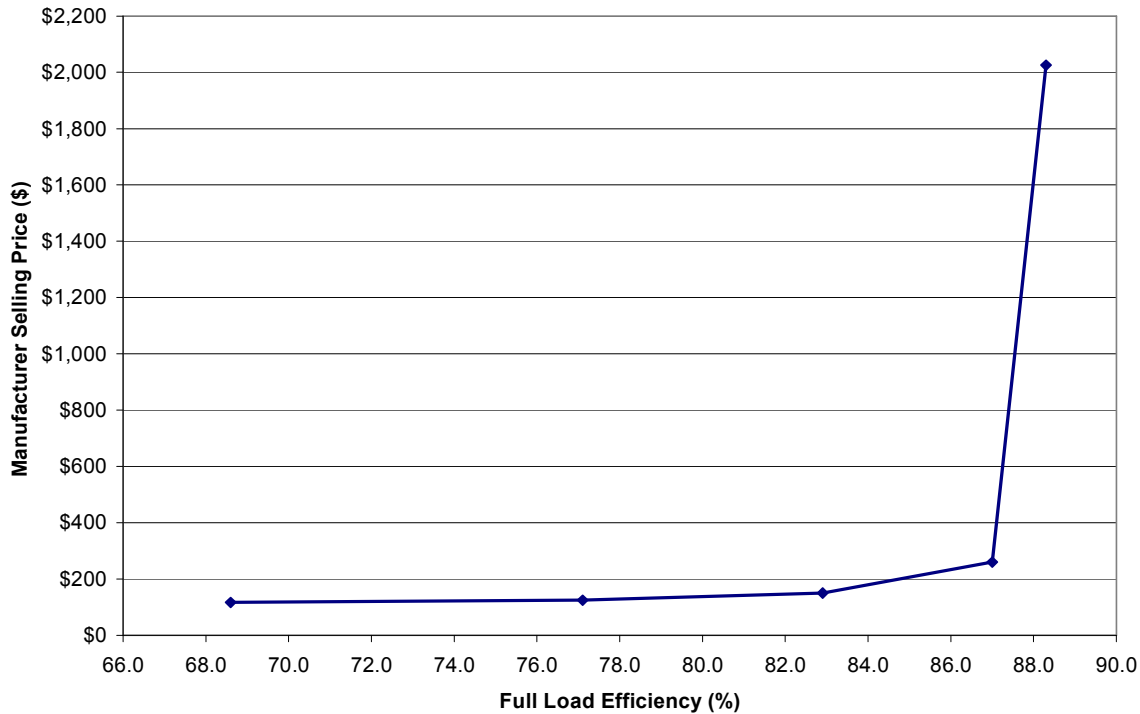


Figure ES.3.5 Capacitor-Start, Capacitor-Run $\frac{3}{4}$ Horsepower, 4-Pole, 56-Frame Engineering Analysis Curve

Table ES.3.8 presents the same engineering analysis results in tabular form, including the full-load efficiency values and the MSPs. Moving from the baseline motor to the premium plus motor, DOE found that the full-load efficiency would increase 18.4 percentage points, for about a 27-percent improvement over the baseline motor. Raising the efficiency to that level caused the MSP to more than double, increasing from \$116.17 for the baseline model to \$259.78 for the premium plus motor.

Table ES.3.8 Efficiency and Manufacturer Selling Price Data for Capacitor-Start, Capacitor-Run Motor

Motor Design	Efficiency (%)	Manufacturer Selling Price (\$)
Baseline	68.6	116.17
Energy Efficient	77.1	124.33
Premium	82.9	149.50
Premium Plus	87.0	259.78
Max Tech	88.3	2,024.82

Table ES.3.9 presents some of the design and performance specifications associated with the five CSCR designs presented above. DOE also provides additional design detail and performance specifications for the premium motor design in the preliminary TSD, appendix 5A.

Table ES.3.9 Capacitor-Start, Capacitor-Run, ¾ Horsepower, 4-Pole, 56-Frame Motor

Parameter	Units	Baseline	Energy Efficient	Premium	Premium Plus	Max Tech
Efficiency	%	68.6	77.1	82.9	87.0	88.3
Line Voltage	V	115	115	115	115	115
Speed	RPM	1,725	1,732	1,735	1,759	1,745
Torque	oz-ft	36.4	37.6	36.6	36.4	35.9
Current	A	11.6	8.7	7.6	7.3	6.3
Steel		24M56	24M56	24M19	29M15	Hiperco 50 0.006
Rotor Conductor Material		Aluminum	Aluminum	Aluminum	Copper	Copper
Main Wire	AWG	20.5	19.5	19.0	20.0	19.0
Auxiliary Wire	AWG	20.0	20.0	21.5	20.0	20.0
Main Wire Weight	lbs	2.201	2.937	3.354	4.124	5.745
Auxiliary Wire Weight	lbs	0.741	0.699	1.104	1.495	1.614
Rotor Conductor Weight	lbs	0.778	1.123	1.136	2.242	3.516
Start Capacitor	µF	550	550	400	550	550
Run Capacitor	µF	20	45	50	50	50
Peak Slot Fill	%	44.7	55.7	61.6	74.2	71.7
Locked Rotor Torque	oz-ft	119.4	119.2	126.7	129.9	156.4
Locked Rotor Current	A	51.2	46.9	39.7	53.3	52.1
Stack Length	in	2.60	2.95	3.10	3.30	4.00
Laminations Per Stack	#	104	118	124	236	667
Housing Weight	lbs	6.10	6.15	6.30	6.50	7.86
Slot Liner	in ²	119.168	135.261	142.164	151.220	183.030
Slot Peg	in ²	14.904	17.503	18.396	19.567	23.660

Manufacturers also submitted data that enabled DOE to create cost efficiency points for the four categories of small electric motors examined. Initially, DOE hoped to compare and present the results of the DOE-generated cost-efficiency curves and the manufacturers' aggregated cost-efficiency points. However, DOE's contractor did not receive input from a sufficient number of manufacturers to allow for public disclosure of the aggregated manufacturer data.

ES.3.4 Energy Use Characterization

The energy use characterization, which assesses the potential energy savings resulting from higher efficiency standards, provides the basis for developing the energy savings used in the LCC and subsequent analyses. Because the analysis is intended to capture and represent typical energy consumption in the field, DOE estimated energy consumption over a representative number of annual operating hours at a certain percent of rated full load.

Small electric motors convert electrical power to useful mechanical work and generally consume energy through (1) energy converted to useful mechanical shaft power, (2) motor

losses, and (3) reactive power.^a Motor losses consist of I^2R (resistance heat) losses, core losses, stray-load losses, and friction and windage losses. Core losses and friction and windage losses are relatively constant with variations in motor loading, while I^2R losses increase with the square of the motor loading. Stray-load losses also depend on loading. DOE models the I^2R losses and stray-load losses as load-dependent losses.

DOE’s analysis of energy use separates motor losses into a constant component and a variable component that depend on motor loading. In DOE’s analysis, the design efficiency of the motor at full load determines the total losses at 100-percent motor loading. DOE then estimates that approximately 50 percent of these losses are load independent, while 50 percent vary as the square of the motor loading.

To calculate the annual kilowatt hours (kWh) use at each efficiency level in each equipment class, DOE used the efficiencies and losses from the engineering analysis, along with estimates of operating hours and motor loading from the determination analysis, for the applications that use equipment containing small electric motors.

Table ES.3.10 shows the average values of operating hours and motor loading for each equipment class, weighted by the shares of each application.

Table ES.3.10 Average Operating Characteristics for Small Electric Motors

Equipment Class	Annual Operating Hours	Motor Loading (% of rated)
Polyphase	2,665	63.2
CSIR	2,557	64.8
CSCR	2,557	64.8

Table ES.3.11 shows the average annual electricity use for each energy efficiency level in each equipment class.

^a 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. While reactive power does not 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.

Table ES.3.11 Average Annual Electricity Use by Efficiency Level for Small Electric Motors

Polyphase		CSIR		CSCR	
Efficiency (%)	kWh	Efficiency (%)	kWh	Efficiency (%)	kWh
75.8	444	62.3	410	68.6	465
84.0	265	70.9	278	80.2	250
85.5	236	73.6	243	82.1	222
86.5	217	75.4	220	83.3	203
88.0	190	78.2	189	85.2	177
90.0	154	81.8	151	87.6	143

See section 2.5 of chapter 2 and chapter 6 of the preliminary TSD for additional detail on the energy use characterization.

ES.3.5 Markups to Determine Installed Price

DOE developed the markups to manufacturer prices to derive installed prices for small electric motors given the MSPs from the engineering analysis. DOE added the supply-chain markups that it developed earlier (along with sales taxes and installation prices) to the MSPs developed in the engineering analysis to arrive at the final installed prices for baseline equipment as well as higher-efficiency equipment. Section 2.6 of chapter 2 of the preliminary TSD summarizes the markup analysis; chapter 7 provides a detailed description of the markup analysis and results.

For small electric motors, DOE defined three distribution channels and estimated their respective shares of shipments in the determination analysis: (1) from manufacturers to original equipment manufacturers (OEMs) and then to end-users through OEM distribution (40 percent of shipments); (2) from manufacturers to wholesale distributors to OEMs and then to end-users through OEM equipment distribution (25 percent of shipments); and (3) from manufacturers to end-users through distributors and retailers (35 percent of shipments). Contractors also play a role in installing motors in equipment. DOE used the same distribution channel types and market shares in the preliminary TSD analysis.

Table ES.3.12 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 three identified channels. Weighting the markups in each channel by its share of shipments yields an average overall baseline markup of 2.42 and an overall incremental markup of 1.75. DOE used these markups for each equipment class.

Table ES.3.12 Summary of Small Electric Motor Distribution Channel Markups

	Direct to OEMs (40%)		Via Distributors to OEMs (25%)		Via Distributors to End- Users (35%)	
	Baseline	Incremental	Baseline	Incremental	Baseline	Incremental
Wholesale Distributor	-	-	1.28	1.10	1.28	1.10
OEM	1.37	1.27	1.37	1.33	-	-
Retail and Post-OEM Distributor	1.43	1.18	1.43	1.18	1.44	1.18
Contractor or Installer	1.10	1.10	1.10	1.10	1.10	1.10
Sales Tax	1.0684		1.0684		1.0684	
Overall	2.30	1.76	2.95	2.03	2.17	1.53

Using these markups, DOE generated motor end-user prices for each efficiency level it considered, assuming that each level represents a new minimum efficiency standard. Because it generated a range of price estimates, DOE describes prices within a range of uncertainty.

ES.3.6 Life-Cycle Cost and Payback Period Analysis

In general, the effect of a new energy conservation standard for a product will result in changes to operating expenses for the user—usually a decrease—and changes in purchase price for the purchaser—usually an increase. DOE analyzed the net effect of new standards on consumers by evaluating the net LCC using the cost-efficiency relationship derived in the engineering analysis, as well as the energy costs derived from the energy-use characterization analysis. Inputs to the LCC calculation include the installed cost to the consumer (consumer purchase price plus installation cost), operating expenses (energy expenses and maintenance costs), the lifetime of the equipment, and a discount rate. Section 2.7 of chapter 2 of this preliminary TSD summarizes the LCC and PBP analysis; chapter 8 provides the detailed description of the LCC and PBP analysis and a detailed description of the results.

DOE calculated the average LCC savings relative to the base case forecast for each equipment class of small electric motors. As mentioned above, the base case consists of the projected pattern of equipment purchases that would occur without new energy conservation standards.

Table ES.3.13 through Table ES.3.15 present key findings from the LCC and PBP analyses DOE performed for this preliminary TSD. Most of the values in the tables are average or median values, though the tables also show the percentage of end users expected to have a net cost (negative LCC savings) or a net benefit (positive LCC savings) at each energy efficiency level. The average LCC savings are calculated relative to the base case, which in the present analysis assumes that all motor purchases are at the baseline energy efficiency level. Chapter 8 of the preliminary TSD presents distributions of LCC and PBP results for each equipment class.

For polyphase motors, the highest energy efficiency level with positive average LCC savings is level 2 at 85.5 percent. DOE estimates that approximately 66 percent of end users would have a net benefit (i.e., LCC decrease) at this level. The increase in average total installed cost at this level (relative to the base case) is \$66, or 14 percent, while operating costs decrease by \$14 or 47 percent.

Table ES.3.13 Polyphase Motors: Life-Cycle Cost and Payback Period Results

Energy Efficiency Level	Efficiency (%)	Life-Cycle Cost			Life-Cycle Cost Savings			Payback Period (years)	
		Average Installed Price (\$)	Average Annual Operating Cost (\$)	Average LCC (\$)	Average Savings (\$)	Consumers with		Median	Average
						Net Cost (%)	Net Benefit (%)		
Baseline	76.37	482	31	692					
1	84.00	523	19	653	40	17.4	82.6	4.0	4.9
2	85.50	548	17	664	29	33.9	66.1	5.5	6.6
3	86.50	663	16	769	- 77	89.3	10.7	13.6	16.5
4	88.00	986	14	1,079	- 386	99.7	0.3	33.5	40.7
5	90.00	2,619	11	2,695	- 2,002	100.0	0.0	2.8	3.7

For CSIR motors, the highest energy efficiency level with positive average LCC savings is level 4 at 75.4 percent; however, DOE estimates that approximately 61 percent of end users would have a net cost (i.e., LCC increase) at this level. The increase in average total installed cost at this level (relative to the base case) is \$52, or 11 percent, while operating costs decrease by \$12 or 43 percent.

Table ES.3.14 Capacitor-Start, Induction-Run Motors: Life-Cycle Cost and Payback Period Results

Energy Efficiency Level	Efficiency (%)	Life-Cycle Cost			Life-Cycle Cost Savings			Payback Period (years)	
		Average Installed Price (\$)	Average Annual Operating Cost (\$)	Average LCC (\$)	Average Savings (\$)	Users with		Median	Average
						Net Cost (%)	Net Benefit (%)		
Baseline	63.30	490	28	648					
1	70.90	510	20	622	26	17.7	82.3	2.8	3.7
2	73.60	526	17	624	24	27.8	72.2	3.8	5.0
3	75.40	542	16	630	18	39.3	60.7	4.8	6.2
4	78.20	579	14	655	- 7	65.1	34.9	7.0	9.0
5	81.80	977	11	1,037	- 390	99.8	0.2	32.1	41.6

For CSCR motors, the highest energy efficiency level with positive average LCC savings is level 3 at 83.3 percent. DOE estimates that approximately 71 percent of end users would have a net benefit at this level. The increase in average total installed cost at this level (relative to the base case) is \$64, or 12 percent, while operating costs decrease by \$19 or 56 percent.

Table ES.3.15 Capacitor-Start, Capacitor-Run Motors: Life-Cycle Cost and Payback Period Results

Energy Efficiency Level	Efficiency (%)	Life-Cycle Cost			Life-Cycle Cost Savings			Payback Period (years)	
		Average Installed Price (\$)	Average Annual Operating Cost (\$)	Average LCC (\$)	Average Savings (\$)	Users with		Median	Average
						Net Cost (%)	Net Benefit (%)		
Baseline	67.91	532	34	724					
1	80.20	561	18	661	63	8.8	91.2	2.0	2.6
2	82.10	578	16	667	57	18.0	82.0	2.9	3.7
3	83.30	598	15	680	45	27.6	72.4	3.9	5.0
4	85.20	656	13	727	- 3	61.8	38.3	6.6	8.5
5	87.60	1,402	10	1,460	- 735	100.0	0.0	41.7	53.4

DOE presents these findings to facilitate review of the LCC and PBP analyses. DOE seeks information and comments relevant to its assumptions, methodology, and results. See chapter 8 of the preliminary TSD for additional detail on the analyses.

ES.3.7 Shipments Analysis

Shipments estimates are a key input into the national impact analysis (see section 2.8 of chapter 2 of the preliminary TSD). DOE also will use shipment estimates as an input to the manufacturer impact analysis (MIA), discussed in section 2.11. DOE developed a set of shipment forecasts for each small electric motor equipment category. Within each category, small electric motor shipments are comprised of products in a number of horsepower ratings and three rotational speeds (3,600 rpm or two-pole, 1,800 rpm or four-pole, and 1,200 rpm or six-pole).

DOE's shipment forecast assumes that sales of small electric motors are driven by macroeconomic activity of the economic sector in which they are used. The small electric motors covered in this preliminary TSD are mainly used in the industrial, agricultural, and commercial sectors. DOE estimates that less than 1 percent of the motors covered in this rule are used in the residential sector. DOE assumed that shipment growth rates for each sector are equal to growth rates in the following economic drivers, provided by AEO 2008 until 2030:

- industrial and agricultural—manufacturing activity (total shipments, manufacturing only, in dollars);
- commercial—commercial floor space; and

- residential—number of households.

The resulting average annual growth rates for shipments of small electric motors from 2015 to 2030 are 1.4 percent for polyphase motors and 1.1 percent for CSIR and CSCR motors. In each case, motor sales follow the sector trend year by year, according to the time series provided by AEO 2008. Therefore, the growth rate is not constant. After 2030, DOE forecasted shipments using the average growth rates for 2020–2030.

Sales of small electric motors may be sensitive to increases in the installed cost. Totally enclosed motors are potential substitutes for the open-construction motors covered in the preliminary analyses. Totally enclosed motors come in the same frame sizes and horsepower ratings and have similar performance characteristics. Today, the incremental cost of using a totally enclosed motor instead of an open-construction motor is approximately 18 percent. If the installed cost of open-construction motors were to increase much beyond 18 percent due to energy conservation standards, there might be some migration to totally enclosed motors.

DOE believes that increases in the installed cost of small electric motors could reduce their purchase due to migration by OEMs to totally enclosed motors or other factors. However, DOE has not found any data that would allow it to estimate the elasticity of small electric motor shipments with respect to purchase price or other factors. Therefore, DOE requests information on the level of price change for the small electric motors covered in the preliminary analyses that would be likely to induce migration to totally enclosed motors, as well as data on what would be an appropriate value to use for purchase price elasticity.

Chapter 9 of the preliminary TSD provides additional detail on the shipments analysis.

Table ES.3.16 presents DOE’s estimate of forecasted small electric motor shipments. Additional detail on the shipments analyses can be found in chapter 9 of the preliminary TSD.

Table ES.3.16 Annual and Cumulative Shipments Forecast for Small Electric Motors

Equipment Class	Annual Shipments (millions)				Cumulative 2015–2045
	2015	2025	2035	2045	
Polyphase	0.638	0.732	0.831	0.944	24.3
CSIR	6.001	6.640	7.423	8.431	219.6
CSCR	0.316	0.349	0.385	0.423	11.4

ES.3.8 National Impact Analysis

The national impact analysis estimates future national energy savings of candidate standards levels and the economic impacts on end users. The analysis measures economic impacts using the net present value (i.e., future amounts discounted to the present) of total end-user costs and savings expected to result from new standards at specific efficiency levels. For a given candidate standard level, DOE calculated the NPV, as well as the NES, as the difference

between a base case forecast and the standards case. NES is estimated in terms of savings in source energy (primary fuel inputs to electricity production and delivery). Chapter 2 of the preliminary TSD presents an overview of the analytical methodology and Chapter 10 provides additional detail on the national impacts analysis.

Table ES.3.17 through Table ES.3.19 show the results of the NES and NPV calculations. An NPV greater than zero shows net savings (i.e., the candidate standard level would reduce customer expenditures relative to the base case in present value terms). An NPV less than zero indicates that the candidate energy conservation standard level would result in a net increase in customer expenditures in present value terms.

For polyphase motors, the highest-efficiency candidate standard level (CSL) that has a positive NPV is CSL 2. For CSIR motors, the highest-efficiency CSL that has a positive NPV is CSL 4. For CSCR motors, the highest-efficiency CSL that has a positive NPV is CSL 3 (using a 7-percent discount rate) or CSL 4 (using a 3-percent discount rate). NPV results can be qualitatively different from LCC results because of differences in either discount rates or long-term trends in energy prices.

Table ES.3.17 Polyphase Small Electric Motors: Cumulative National Energy Savings and Net Present Value Results

Analysis	Discount Rate (%)	Candidate Standard Level				
		CSL 1	CSL 2	CSL 3	CSL 4	CSL 5
NES (quads)	--	0.217	0.255	0.280	0.315	0.362
NPV (billion 2007\$)	3	0.59	0.46	-0.87	-4.81	-25.39
	7	0.23	0.16	-0.48	-2.38	-12.29

Table ES.3.18 Capacitor-Start, Induction-Run Small Electric Motors: Cumulative National Energy Savings and Net Present Value Results

Analysis	Discount Rate (%)	Candidate Standard Level				
		CSL 1	CSL 2	CSL 3	CSL 4	CSL 5
NES (quads)	--	1.095	1.434	1.646	1.946	2.314
NPV (billion 2007\$)	3	3.79	3.86	3.27	0.63	-43.31
	7	1.51	1.45	1.10	-0.26	-21.62

Table ES.3.19 Capacitor-Start, Capacitor-Run Small Electric Motors: Cumulative National Energy Savings and Net Present Value Results

Analysis	Discount Rate (%)	Candidate Standard Level				
		CSL 1	CSL 2	CSL 3	CSL 4	CSL 5
NES (quads)	--	0.114	0.129	0.138	0.151	0.168
NPV (billion 2007\$)	3	0.47	0.44	0.37	0.10	-4.30
	7	0.19	0.18	0.14	0.00	-2.14

ES.3.9 Preliminary Manufacturer Impact Analysis

The preliminary manufacturer impact analysis focuses on manufacturers of small 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 small 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 small 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 small 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.4 IDENTIFICATION OF ISSUES FOR WHICH DOE SEEKS PUBLIC COMMENT

DOE is interested in receiving comments on all aspects of this preliminary TSD, particularly on the following issues.

ES.4.1 Coverage of Small Electric Motors

The term “small electric motor” means a NEMA general-purpose alternating-current single-speed induction motor, built in a two-digit frame number series in accordance with NEMA MG1–1987. These motors include polyphase and single-phase motors and include non-servo three-phase motors; capacitor-start, induction-run motors; and capacitor-start, capacitor-run motors. These motors all have a 42-, 48-, or 56-frame size (or metric equivalent) and are open construction. DOE recognizes that the coverage for the current activity is slightly narrower than that considered for the determination analysis because DOE is now reading the statutory definition of small electric motor as being applicable only to motors with an open construction. In the determination analysis, coverage had been interpreted as encompassing both open and totally enclosed small electric motors. DOE invites interested parties to comment specifically on its interpretation of coverage for the preliminary analyses. If interested parties do not agree with DOE’s interpretation, DOE requests specific legal interpretation and justification for any dissenting viewpoints. Please refer to section 2.2.1 of chapter 2 of the preliminary TSD.

ES.4.2 Technology Options

DOE invites comments on the list of technology options developed in the technology assessment. DOE invites comment on the completeness and description of these technology options. Please refer to section 2.2.3 of chapter 2 of the preliminary TSD.

ES.4.3 Screening Analysis

DOE invites comments on the three technology options that were screened out of the analysis—radial air gaps below ten thousandths of an inch, plastic bonded iron powder, and permanent magnet electric motors. Please refer to section 2.3 of chapter 2 of the preliminary TSD.

ES.4.4 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 four representative units analyzed. DOE is also interested in comment on the baseline models selected, and whether these are the appropriate baseline models on which to base the engineering analysis. Finally, 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 section 2.4 of chapter 2 of the preliminary TSD.

ES.4.5 Engineering Analysis Results

DOE invites comments on the findings of the engineering analysis. DOE also invites comment on the decision to drop one of the four motors from the preliminary TSD analysis due to the similar findings between the 48- and 56-frame size CSIR motors.

ES.4.6 Reactive Power Losses

Motors can induce costs on the electrical system and their owners not only through their consumptive energy losses, but also through the production of reactive power. Reactive power arises in inductive loads that shift the phase of the alternating-current power and reflect a portion of the incoming power back to the electrical system. Reactive power results in higher electrical power circuit currents and can induce losses on the customer side of the electrical meter and the electric power system in general.^b

^b Reactive power occurs when a coil (such as in a motor) or capacitor (such as in a consumer appliance) is connected to an alternating current power supply (e.g., generator), the coil or capacitor stores electrical energy during one-fourth of an alternating current cycle. But then during the next quarter-cycle, the coil or capacitor dumps all the stored energy back into the distant alternating current power supply. In other words, where electrical power is delivered from a generator to a motor, reactive power travels in both directions, between the generator and the motor. This leads to an extra current in the power lines that generates heat in the power lines, but which is not used to provide energy to the appliance. The coil or capacitor causes electrical energy to begin "sloshing" back and forth between the appliance and the distant alternating current generator. Electric companies must install heavier wires to tolerate this excess current and will charge an extra amount for this "unused" energy.

Because of the losses that reactive power can create in the electrical system, many utilities charge a reactive power penalty for industrial and commercial customers that do not correct or mitigate reactive power problems with their loads.

Utilities and large customers usually correct reactive power problems by adding capacitors to the system. Capacitors shift the phase of an alternating-current power signal in the opposite direction as alternating-current loads and thus can efficiently correct reactive power problems. Depending on the efficiency of the electrical system and power factor correction measures, reactive power may or may not result in significant consumptive energy losses.

Typically, reactive power is about the same size as other consumptive losses of a motor. However, in an efficiently corrected distribution system (i.e., one with a sufficient number of capacitors) only a relatively small fraction of this power should result in consumptive losses because the capacitors confine the higher electrical power circuit currents to a small portion of the electrical system. Thus, while DOE expects to include a cost factor to account for reactive power effects later in the NOPR analysis, DOE does not expect to include consumptive losses because they are likely to be small. DOE invites comments by interested parties on this approach and any data that they may have on the fraction of motor reactive power that may result in consumptive losses on the customer circuits and electrical power system in general. Please refer to section 2.5 of chapter 2 of the preliminary TSD.

ES.4.7 Product Energy Efficiency in the Base Case

For the LCC analysis, DOE analyzed candidate standard levels relative to a base case. This requires an estimate of the distribution of product efficiencies in the base case (i.e., what consumers would have purchased in 2015 in the absence of new standards). In other rulemakings, DOE often used the distribution of product efficiencies currently in the marketplace to develop its distribution estimate in the base case. DOE found some indications of purchasing of higher-efficiency motors, but it did not have detailed data on what proportion of sales such motors account for at present. For the preliminary TSD, DOE estimated an average efficiency in the base case close to the baseline efficiency levels. DOE requests comments on this estimate, as well as information on the distribution of equipment efficiencies currently in the marketplace. Please refer to section 2.7 of chapter 2 of the preliminary TSD.

ES.4.8 Purchase Price Elasticity

An increase in the installed cost of small electric motors could reduce their purchase due to migration by OEMs to totally enclosed motors, which are not covered by DOE standards, or other factors. However, DOE has not found any data that would allow it to estimate the elasticity of small electric motor shipments with respect to change in their purchase price or other factors. DOE requests information on the level of price change for covered small electric motors that would be likely to induce migration to totally enclosed motors, as well as data on what would be an appropriate value for purchase price elasticity. Please refer to section 2.8.1 of chapter 2 of the preliminary TSD.

ES.4.9 Enforcement for Motors in OEM Equipment

Of particular concern is the enforcement of standards on small electric motors contained within imported OEM equipment. Subpart U, "Enforcement," of 10 CFR 431 describes violations of the energy conservation standards, and specific procedures that DOE will follow in pursuing alleged non-compliance of an electric motor. DOE intends to apply these procedures to small electric motors. Nevertheless, as a practical matter, DOE understands that in some cases a small electric motor is imported as a component that operates in or drives a larger piece of equipment. Consequently, direct access to the component small electric motor for examination may be difficult or impossible and shipping documents for the OEM equipment may not provide sufficient information that extends to the efficiency of that small electric motor. DOE understands that enforcement of energy efficiency requirements for small electric motors is unlike other consumer products or commercial equipment and if it is difficult to enforce efficiency standards for small electric motors contained imported OEM equipment, then this may increase competitive burdens on domestic OEM equipment manufacturers relative to foreign OEM equipment manufacturers. DOE invites comment on issues of enforcement. DOE also requests data and information from interested parties that can assist in evaluating the potential impact of standards on moving OEM equipment assembly and manufacture offshore under conditions of weak or incomplete regulatory standards enforcement.

ES.4.10 Monetary Value of Carbon Dioxide Emissions Reduction

DOE invites comment on the monetary value of carbon dioxide emissions reduction. DOE will use monetary values to represent the potential value of such emissions reductions. DOE invites comment on methods for estimating the net monetary value of carbon dioxide emissions reductions. DOE also invites comment on which data and reports provide information regarding widely accepted values that may be used in DOE's analyses. Please refer to section 2.14 of chapter 2 of the preliminary TSD.