Energy Conservation Standards
Rulemaking Framework Document for
Electric Motors

U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Building Technologies Program

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LIST OF ACRONYMS

AEO	Annual Energy Outlook
BT	Building Technologies Program
CAIR	Clean Air Interstate Rule
CFR	Code of Federal Regulations
CSL	Candidate standard level
DOE	U.S. Department of Energy
DOJ	U.S. Department of Justice
EERE	Office of Energy Efficiency and Renewable Energy
EIA	Energy Information Administration
EISA	Energy Independence and Security Act of 2007
EPACT	Energy Policy Act of 1992
EPCA	Energy Policy and Conservation Act
FR	Federal Register
GRIM	Government Regulatory Impact Model
IEEE	Institute of Electrical and Electronics Engineers, Inc.
LCC	Life-cycle cost
NEMA	National Electrical Manufacturers Association
NEMS	National Energy Modeling System
NES	National energy savings
NOPR	Notice of proposed rulemaking
NPV	Net present value
OMB	U.S. Office of Management and Budget
R&D	Research and development
RPM	Revolutions per minute
SG&A	Selling, general, and administrative costs
SNOPR	Supplementary notice of proposed rulemaking
TSD	Technical support document
TSL	Trial standard level
U.S.C.	United States Code

Rulemaking Framework Document for Electric Motors

1 INTRODUCTION

The U.S. Department of Energy (DOE or Department) Appliances and Commercial Equipment Standards Program, within the Office of Energy Efficiency and Renewable Energy (EERE) Building Technologies Program (BT), develops and promulgates test procedures and energy conservation standards for consumer appliances and certain commercial and industrial equipment. An August 2009 DOE report to Congress identifies the energy conservation standards rulemakings that DOE has scheduled for completion and explains many of the techniques DOE will apply during the rulemaking process to meet this schedule.[1]

This document describes the procedural and analytical approaches DOE anticipates using to evaluate energy conservation standards for electric motors. See section 1.1 below for a discussion of the statutory authority for this rulemaking. The purpose of this document is to inform interested parties about the process DOE will follow for the standards rulemaking for these motors and to encourage and facilitate interested party input during the rulemaking. This document is merely the starting point for potentially amending standards and is not a definitive statement with respect to any issue to be determined in the rulemaking.

Section 1 provides an overview of the rulemaking process. Sections 2 through 17 discuss analyses DOE intends to conduct to fulfill the statutory requirements and adhere to guidance for this standards rulemaking. For the electric motor categories examined in this rulemaking, DOE will perform a set of analyses to determine whether amended energy conservation standards are technologically feasible, economically justified, and would result in significant conservation of energy.

DOE will maintain information regarding this rulemaking on its website at: http://www1.eere.energy.gov/buildings/appliance_standards/commercial/electric_motors.html.

DOE invites comments from interested parties on all aspects of the material presented in this document. DOE especially seeks comment on issues set out in comment boxes like this one. DOE uses comment boxes to highlight certain issues and ask specific questions on the approaches it is proposing to follow.

1.1 The Appliances and Commercial Equipment Standards Program

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,

[1] "Implementation Report: Energy Conservation Standards Activities" available at: http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/seventh_report_congress_aug_09.pdf.

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 that the Secretary shall 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))

As described previously, EISA 2007 constitutes the most recent amendment to EPCA and energy conservation standards for electric motors. Because these amendments go into effect December 19, 2010, DOE is required by statute to publish a final rule determining whether to amend the EISA 2007 energy conservation standards for electric motors by December 19, 2012. 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 go into effect December 19, 2015. This framework document describes how DOE proposes to conduct the in-depth analysis for this rulemaking process.

1.2 Overview of Definition and Sub-Categories of Covered Electric Motors

Parallel to this rulemaking, DOE is developing an electric motors test procedure supplemental notice of proposed rulemaking (SNOPR) primarily focused on updating various definitions and incorporations by reference related to the current test procedure. Because the SNOPR is not yet published, today's framework document describes the procedural and analytical approaches DOE anticipates using to evaluate energy conservation standards for electric motors without consideration of any changes that may be proposed in the SNOPR.

As defined under EPCA, as amended by EISA 2007, "electric motor" means a subtype I or subtype II general purpose electric motor. (42 U.S.C. 6311(13)) Typical general purpose electric motors, both subtype I and subtype II, employ a stator and a squirrel-cage rotor.[2] The squirrel-cage rotor unit consists of a laminated steel core mounted on a steel shaft. In this squirrel-cage rotor configuration, the rotor consists of solid conductor bars that are interconnected at either end with solid-conductor end rings. The stator consists of a hollow cylindrical core formed by a stack of thin steel laminations. Insulated copper windings are assembled into slots formed around the inner circumference of the stator steel laminations. The stator winding carries current through one slot and then back through a companion slot located

[2] The "squirrel-cage" rotor has a series of aluminum bars cast lengthwise into the rotor laminations. These bars are connected with rings located at each end of the stack. Absent the laminated steel core, the assembly of bars and end rings have the appearance of a squirrel cage, hence the industry nomenclature for this type of construction.

approximately one pole pitch[3] distant from the first slot. Opposing and attracting magnetic forces acting between the stator and rotor of the motor cause the rotor to spin and produce torque.

When the stator windings are energized by a polyphase electrical source, a radially directed magnetic flux is established in the "air gap" between the rotor and the stator. This flux rotates at a speed determined by the electrical frequency and number of poles given by the stator-winding configuration. For example, with 60 hertz excitation and a two-pole (or one-pole-pair) winding, the flux rotates at a so-called "synchronous" speed of 60 revolutions per second or 3,600 revolutions per minute (rpm). The flux produced by the energized stator windings envelops the rotor cage bars and, due to its motion, induces current to flow in these conducting cage bars.

The interaction of the alternating stator flux and the rotor bar currents develops the motor's drive torque. When the driven equipment, such as a pump, fan blade, or compressor cylinder, exerts torque on the motor, a difference arises between the synchronous speed and the actual speed of the motor, which is termed "slip." Slip is often measured as a percentage. For a four-pole motor with a slip rating of 5 percent, the synchronous speed is 1,800 rpm, but the motor when fully loaded will rotate 5 percent slower, or at 1,710 rpm. Thus, the actual speed of the motor when fully loaded is slightly less than the synchronous motor speed.

EISA 2007 established energy conservation standards for four main categories of motors: general purpose electric motors (subtype I), general purpose electric motors (subtype II), fire pump motors, and National Electrical Manufacturers Association (NEMA) Design B general purpose electric motors (from 200 hp through 500 hp). As background, the following subsections provide some additional details about these categories of motors.

1.2.1 General Purpose Electric Motors (Subtype I)

Section 313(a)(2) of EISA 2007 established the following definition of general purpose electric motor (subtype I):

General purpose electric motor (subtype I). The term "general purpose electric motor (subtype I)" means any motor that meets the definition of "General Purpose" as established in the final rule issued by the Department of Energy entitled "Energy Efficiency Program for Certain Commercial and Industrial Equipment: Test Procedures, Labeling, and Certification Requirements for Electric Motors" (10 CFR 431), as in effect on the date of enactment of the Energy Independence and Security Act of 2007 [enacted Dec. 19, 2007].

General purpose electric motors (subtype I) are polyphase motors that range from 1 horsepower to 500 horsepower and are available in two-pole, four-pole, six-pole, and eight-pole configurations. Additionally, general purpose electric motors (subtype I) are characterized as NEMA Design A and NEMA Design B motors.

NEMA MG1-2009, paragraph 1.19.1.1, defines a Design A motor as "a squirrel-cage motor designed to withstand full-voltage starting and developing locked-rotor torque as shown in

[3] Pole pitch, when defined in angular dimensions, is the angular distance between consecutive poles. For a four-pole motor, the pole pitch is 360°/4 or 90°. Likewise, for a motor with *n* poles, the pole pitch is 360°/*n*.

12.38, pull-up torque as shown in 12.40, breakdown torque as shown in 12.39, with locked-rotor current higher than the values shown in 12.35.1 for 60 hertz and 12.35.2 for 50 hertz, and having a slip at rated load of less than 5 percent." Typical applications where these motors are used include fans, blowers, and pumps.

NEMA MG1-2009, paragraph 1.19.1.2, defines a Design B motor as "a squirrel-cage motor designed to withstand full-voltage starting, developing locked-rotor, breakdown, and pull-up torques adequate for general application as specified in 12.38, 12.39, and 12.40, drawing locked-rotor current not to exceed the values shown in 12.35.3 for 60 hertz and 12.35.3 for 50 hertz, and having a slip at rated load of less than 5 percent." Typical applications where these motors are used include fans, blowers, centrifugal pumps, and compressors.

EISA 2007 established energy conservation standards for these two designs of general purpose electric motors (subtype I). Energy conservation standards for Design A and Design B motors, with horsepower ratings from 1 horsepower up to and including 200 horsepower and built with two-, four-, or six-pole configurations, were increased from the EPACT 1992 levels to the "NEMA Premium" levels that were previously voluntary. (Pub. L. No. 110–140, § 313(b)(2)(A)) EISA 2007 also set new standards for the previously uncovered NEMA Design B motors with horsepower ratings greater than 200 horsepower up to and including 500 horsepower and built with a two-, four-, six-, or eight-pole configuration. (Pub. L. No. 110–140, § 313(b)(2)(D))

EISA 2007 explicitly cited NEMA Design B motors but did not provide a definition. Therefore, in its Notice of Proposed Rulemaking (NOPR) on test procedures for electric motors, DOE proposed a modified version of the MG1-2009 definition above. (73 Fed. Reg. 78220, 78235 (Dec, 22, 2008)) The modified definition strikes the clause referring to 50 hertz motors because they are not covered. It also corrects a typographical error concerning locked-rotor current requirements. Finally, it adds the clause "for motors with fewer than 10 poles" to the end of the scope, because no standards for motors built with more than 8 poles were prescribed. DOE did receive comments regarding this modified definition. The proposed definition is reproduced below:

"*NEMA Design B, general purpose electric motor* means a squirrel-cage motor designed to withstand full-voltage starting, developing locked-rotor, breakdown, and pull-up torques adequate for general applications as specified in sections 12.38, 12.39, and 12.40, respectively, of NEMA Standards Publication MG1-2009, drawing locked rotor current not to exceed the values shown in MG1-12.35.1 for 60 hertz motors, and having a slip at rated load of less than 5 percent for motors with fewer than 10 poles."

NEMA MG1-2009 establishes the same torque requirements for both NEMA Design A and NEMA Design B motors. However, NEMA Design B motors must be designed such that their locked-rotor or starting current is less than that established for NEMA Design A motors. For this reason, a NEMA Design B motor is often used instead of a NEMA Design A motor. These motors are often used in pumps, fans, blowers, and compressors.

1.2.2 Fire Pump Motors

EISA 2007 also established energy conservation standards for fire pump motors, but did not define the term "fire pump motor." (Pub. L. No. 110–140, § 313(b)(2)(B)) As with NEMA Design B general purpose electric motors, DOE sought to clarify this definition in its electric motors test procedures NOPR. (73 Fed. Reg. 78220 (Dec. 22, 2008)) The following definition was proposed as follows:

"*Fire pump motor* means a Design B polyphase motor, as defined in NEMA MG1-2006, rated 500 horsepower (373 kW) or less, 600 volts or less, and that is intended for use in accordance with the National Fire Protection Association (NFPA) Standard 20-2007, 'Standard for the Installation of Stationary Pumps for Fire Protection.'"

DOE understands that a fire pump motor constitutes a particular subset of general purpose electric motors that, in addition to EISA 2007 requirements for energy efficiency, are covered by other performance and construction requirements such as under NFPA 20-2010 and UL 1004-5. DOE plans to address this concern in the SNOPR.

1.2.3 General Purpose Subtype II Electric Motors

Section 313(a)(2) of EISA 2007 established the following definition of a general purpose electric motor (subtype II):

General purpose electric motor (subtype II): The term 'general purpose electric motor (subtype II)' means motors incorporating the design elements of a general purpose electric motor (subtype I) that are configured as 1 of the following:

(i) A U-Frame Motor.
(ii) A Design C Motor.
(iii) A close-coupled pump motor.
(iv) A Footless motor.
(v) A vertical solid shaft normal thrust motor (as tested in a horizontal configuration).
(vi) An 8-pole motor (900 rpm).
(vii) A poly-phase motor with voltage of not more than 600 volts (other than 230 or 460 volts.

U-frame motors have an oversized frame when compared to the T-frame designs used in subtype I general purpose electric motor designs. This larger frame enables the motor to dissipate heat and withstand overload conditions for a longer period. These motors typically range from 1 horsepower to 300 horsepower, and can be found in two-pole, four-pole, and six-pole configurations. U-frame motors are often used in automotive assembly plants that have special energy conservation standards.

A Design C motor is an alternating-current induction, squirrel-cage motor that typically has high starting torque and low slip. This design is often used in applications where loads are high at the start, but typically run at rated full load and are not subject to high overload demands once the motor running speed has been reached. Design C motors, when operating under the rated load, have a slip value of less than 5 percent, and they are usually used in crushers and conveyers over 50 horsepower.

Close-coupled pump motors are C-face motors with or without a base, but with a special shaft that mounts to a pump. These motors typically range from 1 horsepower to 60 horsepower, and can usually be found in two-pole and four-pole configurations. This category of motor is often used with adjustable speed drives.

Footless motors are C-face or D-flange motors without a base. These motors usually mount to gearboxes, pumps, or compressors. Similar to the close-coupled pump motors, the footless motors are often used with adjustable speed drives.

Vertical solid shaft normal thrust motors, also known as P-base motors, are mounted to a pump. These motors typically range from 1 horsepower to 250 horsepower, and are available in two-pole, four-pole, six-pole, and eight-pole configurations. They are often used with adjustable speed drives in water plants and process industries.

Eight-pole motors have a synchronous speed of 900 RPM and are often used in process industries.

Polyphase motors with voltage of not more than 600 volts, but with a voltage other than 230 or 460 volts, do not have a defined mounting type. The most typical voltages found for this motor classification are 200 volts and 575 volts. This motor classification also includes IEC metric motors, with 90 mm frames and larger.

In this rulemaking, DOE is also considering expanding the scope of coverage for electric motors standards as necessary to carry out the goals of EPCA, as authorized under 42 U.S.C 6312(b).

DOE welcomes comment on DOE's potential expansion of scope of coverage for electric motors. In particular, DOE is interested in any electric motors that interested parties believe may be able to achieve energy savings that will be economically justified and technologically feasible. DOE also requests comment on whether any clarifications or modification to the definitions of electric motors should be made to prevent potential circumvention of energy conservation standards.

1.3 Overview of the Rulemaking Process

As discussed in Section 1.1, EPCA requires DOE to develop both test procedures and energy conservation standards for electric motors. Test procedures are used by manufacturers to evaluate compliance with energy conservation standards.

1.3.1 Test Procedures

On October 5, 1999, DOE published in the *Federal Register* a final rule regarding test procedures for electric motors. (64 Fed. Reg. 54114) As described in section 1.2, DOE is currently developing an SNOPR primarily focused on updating various definitions and incorporations by reference related to the current test procedure. Until those updates are finalized, manufacturers are required to determine compliance using current test procedures.

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DOE's SNOPR may incorporate by reference portions of test procedures and definitional information from relevant sources, including the Institute of Electrical and Electronics Engineers, Inc. (IEEE), NEMA, Canadian Standards Association (CSA) International, and the International Electrotechnical Commission (IEC). DOE plans to address in further detail possible updates to the current procedures and definitions that have been incorporated by reference in the above-mentioned SNOPR.

Item 1 *DOE welcomes comment on any additional test procedures that should be considered or comments about the test procedures listed.*

1.3.2 Rulemaking Process and Participation of Interested Parties

EPCA specifies that any standard DOE prescribes for consumer products and certain equipment, including electric motors, shall be designed to achieve the maximum energy efficiency improvement that is technologically feasible and economically justified as required by EPCA. (42 U.S.C. 6295(o)(2)(A), 6316(a)) Additionally, DOE must determine that the establishment of a new or amended energy conservation standard will result in significant energy conservation. (42 U.S.C. 6295(o)(3)(B), 6316(a)) Under EPCA, when DOE evaluates any new or amended energy conservation standard for covered products or certain equipment, including electric motors, DOE considers the following seven factors to the greatest extent practicable when determining whether a standard is economically justified:

(1) The economic impact of the standard on the manufacturers and on the consumers of the products subject to such standard;
(2) The savings in operating costs throughout the estimated average life of the covered products in the type (or class) compared to any increase in the price, or in the initial charges for, or maintenance expenses of the covered products which are likely to result from the imposition of the standard;
(3) The total projected amount of energy (or as applicable, water) savings likely to result directly from the imposition of the standard;
(4) Any lessening of the utility or the performance of the covered products likely to result from the imposition of the standard;
(5) The impact of any lessening of competition, as determined in writing by the Attorney General, that is likely to result from the imposition of the standard;
(6) The need for national energy and water conservation; and
(7) Other factors the Secretary considers relevant.

(42 U.S.C. 6295(o)(2)(B)(i), 6316(a))

The process for developing energy conservation standards involves analysis, public notice and comment and consultation with interested parties. Such interested parties generally include manufacturers, consumers, energy conservation and environmental advocates, State and Federal agencies, and any other groups or individuals with an interest in energy conservation standards and test procedures. DOE considers participation from interested parties to be a very important part of the rulemaking process. DOE actively encourages the participation and interaction of all interested parties during the comment period provided at each stage of the

rulemaking. The broad array of interested parties who routinely provide comments promotes a balanced discussion of critical information required to conduct the standards rulemaking, beginning with public comment on the framework document.

DOE involves interested parties through a variety of means when developing test procedure and energy conservation standards rulemakings. As discussed in further detail below, the standards rulemaking process involves three public notices, which are published in the *Federal Register* following publication of the framework document. Publication of the preliminary analysis as well as the notice of proposed rulemaking (NOPR) will be accompanied by public meetings to solicit comment from interested parties to enhance the rulemaking process.

- *Preliminary Analysis and Notice of Public Meeting* (section 1.4). The preliminary analysis is designed to publicly vet the models and tools that DOE will use in the rulemaking, and to facilitate public participation before the proposed rule stage. Candidate standard levels (CSLs), which span the range of efficiencies from baseline equipment to the most efficient technology, are the basis for demonstrating the functionality of the models and tools.
- *Notice of Proposed Rulemaking* (section 1.5). The NOPR presents a discussion of: comments received in response to the preliminary analysis; DOE's analysis of potential standards impacts on consumers, manufacturers, and the Nation and how DOE weighs these impacts; and the proposed standard levels for public comment.
- *Final Rule* (section 1.6). The final rule presents a discussion of: comments received in response to the NOPR; the revised analysis of the standards' impacts and how DOE weighs the impacts; and the standard levels DOE is adopting. The final rule also establishes the standards' compliance date.

DOE intends to follow the schedule below for this electric motors rulemaking.

Table 1.3.1 Rulemaking Schedule for Electric Motors Energy Conservation Standard

Rulemaking Notice	Issuance Date
Preliminary Analysis	07/2011
NOPR	06/2012
Final Rule	12/2012

EPCA provides that any amended energy conservation standard for electric motors will apply to products manufactured on or after December 19, 2015. (42 U.S.C. 6313(b)(3)(B)(i))

1.4 Preliminary Analysis

During the preliminary analysis phase of the rulemaking DOE presents the models and tools it will use to conduct the four principle analyses that comprise the preliminary analysis–the engineering analysis, life-cycle cost analysis, national impact analysis, and preliminary manufacturer impact analysis. Before conducting the engineering analysis, DOE typically first

identifies equipment technology options to increase efficiency and then preliminarily determines whether to retain that option for detailed analysis or to eliminate it from further consideration. This process includes a market and technology assessment (section 3) and a screening analysis (section 4). DOE applies four screening criteria in the screening analysis to determine which technology options to eliminate from further consideration, including: (1) technological feasibility; (2) practicability to manufacture, install, and service; (3) adverse impacts on product utility or availability; and (4) adverse impacts on health or safety. Technologies that pass through the screening analysis are referred to as design options in the engineering analysis.

DOE consults with interested parties and independent technical experts to identify the design options, efficiency levels, or key issues that DOE will consider in the rulemaking. DOE initiates that dialogue with this framework document, the public meeting following its publication, and the request for public comment. These activities will provide an opportunity for input into the structural and analytical approach planned for this energy conservation standards rulemaking.

Next, DOE considers design options or efficiency levels for each product class. DOE uses these design options or efficiency levels to collect manufacturer cost data, historical shipment data, shipment-weighted average efficiency data, and preliminary manufacturer impact data (*e.g.*, capital conversion expenditures, marketing costs, and research and development costs). DOE then conducts the principal analyses, including: (1) the engineering analysis (section 5); (2) the consumer life-cycle cost (LCC) and payback period (PBP) analyses (section 8); (3) the national impact analysis, which considers national energy savings (NES) and consumer net present value (NPV) (section 10); and (4) a preliminary manufacturer impact analysis (section 6). DOE will present the results of these analyses in the preliminary analysis technical support document (TSD).

Based on the results of the preliminary analysis described above, DOE selects CSLs[4] from the energy efficiency levels considered in the preliminary analysis. Publication of DOE analysis of various CSLs in the preliminary analysis will enable interested parties to review the spreadsheet models that underpin the analyses and provide DOE with feedback so that the models can be refined. In the next stage of rulemaking, the NOPR, DOE generally considers energy efficiency levels or design options that span the full range of technologically achievable efficiencies. The range of levels DOE typically analyzes includes:

- The baseline efficiency level (*i.e.*, the minimum level), which is defined by the type of equipment with the lowest energy efficiency level currently sold on the market for a given category. For equipment categories where minimum energy conservation standards already exist, the baseline efficiency level is typically defined by the existing energy conservation standard;

- The level with the minimum LCC or greatest LCC savings;

[4] CSLs are a set of efficiency levels considered in the preliminary analysis that spans the range of efficiencies from baseline equipment to maximum technologically feasible equipment.

- The highest energy efficiency level or lowest energy consumption level that is technologically feasible (*i.e.,* maximum technologically-feasible (max-tech)); and

- Levels that incorporate noteworthy technologies or fill in large gaps between other efficiency levels considered.

At the preliminary analysis stage, DOE uses analytical models and tools to assess the different product classes at each efficiency or energy use level analyzed. Many of these analytical models and tools are in the form of spreadsheets, which are also used to conduct the LCC and PBP analyses and to determine the national energy savings and NPV of CSLs.

DOE will make the spreadsheet tools used in the preliminary analysis and results of the preliminary analysis available on its website for review.[5] DOE will also make a TSD available containing the details of all the analyses performed to date when it publishes the preliminary analysis. After publication of the preliminary analysis, DOE will provide a 60-day public comment period and hold one public meeting. At that point, DOE encourages interested parties to develop joint recommendations for standard levels.

1.5 Notice of Proposed Rulemaking

During the NOPR phase of standard rulemaking, DOE makes revisions to the preliminary analysis, and selects proposed standard levels for each product class. In developing the NOPR for electric motors, DOE will first review and consider all the comments it received after the preliminary analysis and public meeting. This process may result in revisions to the engineering, life-cycle cost, or national impact analyses. DOE will also conduct additional economic and environmental impact analyses at this stage of the rulemaking. These analyses generally include a consumer LCC subgroup analysis (section 11), a complete manufacturer impact analysis (section 12), a utility impact analysis (section 13), an employment impact analysis (section 14), an environmental assessment (section 15), and a regulatory impact analysis (section 17).

The results of all these analyses and all of DOE's analyses will be available on DOE's website for review and comment. Based on interested party comments, DOE may further revise the analyses. This analytical process ends with the selection of a proposed standard level (if any) for each product class, which DOE will later present in the NOPR. DOE selects the proposed standard levels from the trial standard levels (TSLs) analyzed during the NOPR phase of the rulemaking (similar to the CSLs analyzed during the preliminary analyses). The NOPR, published in the Federal Register, will document the evaluation and selection of any proposed standards levels, along with a discussion of other TSLs considered but not selected (and the reasons for not selecting them).

[5] All materials associated with the rulemakings for electric motors test procedures and energy conservation standards are available on DOE's website at: http://www1.eere.energy.gov/buildings/appliance_standards/commercial/electric_motors.html.

In the NOPR, DOE will identify the max-tech efficiency level for each product class. If DOE proposes a level lower than max-tech, it will sequentially explain the reasons for eliminating higher levels, beginning with the highest level considered. DOE will present the analytical results in the NOPR. The details of the analysis will be provided in an accompanying TSD.

DOE considers many factors in selecting proposed standards levels. These factors and criteria, contained in EPCA, consider the benefits, costs, and impacts of energy conservation standards. Again, at this phase DOE encourages interested parties to develop joint recommendations for standard levels. DOE will carefully consider such recommendations in its decision-making process.

DOE will provide the Department of Justice (DOJ) with copies of the NOPR and TSD to solicit feedback on the proposed standard levels' impact on competition as required by EPCA. (42 U.S.C. 6295(o)(2)(B)(i)(V) and (B)(ii)) A public meeting and a 60-day public comment period will follow publication of the NOPR.

1.6 Final Rule

After publication of the NOPR, DOE will consider the public comments that it receives on the proposal (including TSLs) and accompanying analyses. On the basis of the public comments, DOE will review the engineering and economic impact analyses and proposed standards and consider modifications where necessary. Before issuing the final rule, DOE will also consider DOJ comments regarding the impacts of the proposed standard levels on competition to determine whether changes to these standard levels are needed.

The standards rulemaking will conclude with the publication of the final rule. DOE will select the final standard level based on the complete record of the standards rulemaking. The final rule will specify the final standard level, explain the basis for its selection, and include the standard compliance date. The final rule will be accompanied by a final TSD.

2 OVERVIEW OF ANALYSES FOR RULEMAKING

The purpose of the analyses conducted in support of the standards rulemaking is to ensure that DOE selects energy conservation standards that achieve the maximum improvement in energy efficiency that is technologically feasible and economically justified, and that will result in significant energy savings, as required by EPCA. Economic justification includes the consideration of economic impacts on domestic manufacturers and consumers, national benefits including environmental impacts, issues of consumer utility, and impacts from any lessening of competition. DOE expects the selection of such standards to achieve the maximum energy savings that are technologically feasible and economically justified without imposing excessive financial burden on any particular party.

Figure 2.1 summarizes the analytical components of the standards-setting process. The "analyses" are presented in the center column. Each analysis has a set of "key inputs," which are data and information required for the analysis. "Approaches" are the methods that DOE will use to obtain key inputs, which may vary depending on the information in question. For example,

some key inputs exist in public databases. DOE will collect other information from interested parties or experts with special knowledge. DOE will develop yet other information independently in support of this rulemaking. The results of each analysis are "key outputs," which feed directly into the rulemaking. Arrows indicate the flow of information between the various analyses. DOE ensures a consistent approach to its analyses throughout the rulemaking by considering each analysis as a part of the overall standards-setting framework.

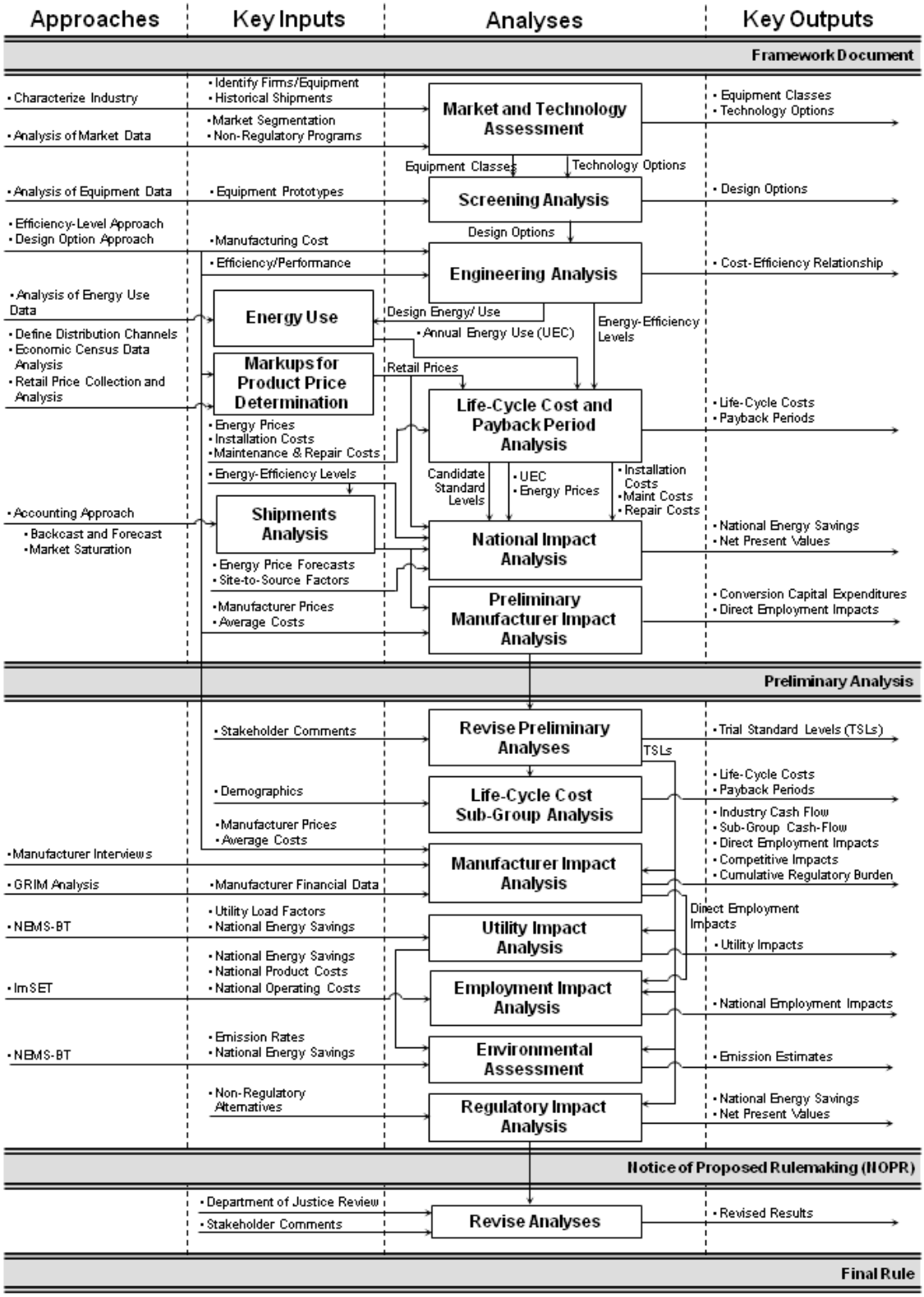

Figure 2.1 Flow Diagram of Analyses Conducted for an Energy Conservation Standard Rulemaking

3 MARKET AND TECHNOLOGY ASSESSMENT

The market and technology assessment will provide information about the manufacturers of electric motors and specifics about the performance attributes of these motors. DOE will use this assessment throughout the rulemaking process. However, the assessment is particularly important at the outset for developing product classes and for identifying technology options that improve the efficiency of electric motors.

3.1 Market Assessment

DOE will qualitatively and quantitatively characterize the structure of the markets for general purpose subtype I and general purpose subtype II electric motors. In the market assessment, DOE will characterize the manufacturers, estimate market shares and trends, and address regulatory and non-regulatory initiatives intended to improve the efficiency or reduce the energy consumption of covered motors.

This market assessment will serve as a resource to guide the analyses that follow. For example, DOE may use historical shipments and prices as an indicator of future shipments and prices. Similarly, DOE plans to use market structure data for the manufacturer impact analysis.

DOE recognizes that there may be limited public information on national shipments, manufacturing costs, channels of distribution, and manufacturers' market shares of electric motors. These types of data would be extremely valuable for conducting analyses to determine if energy conservation standards are economically justified and will result in significant energy savings. Therefore, DOE encourages interested parties to submit any available data that pertain to these areas of interest and that would improve DOE's understanding of the electric motors market.

Interested parties that want to submit valuable, confidential information to DOE have two options. This data may be provided under a confidentiality agreement with DOE's contractor responsible for this part of the rulemaking analysis. In other rulemakings, the contractor regularly works with confidential data from manufacturers and other organizations. The contractor prepares aggregated results for DOE's analyses that do not divulge the sensitive nature of the raw data, but enable other interested parties to review and comment on the aggregated dataset.

Alternatively, interested parties may submit confidential data to DOE in accordance with 10 CFR 1004.11. Interested parties should indicate in writing which data should remain confidential.

DOE is developing a model database of commonly available electric motors based on the most recent manufacturer catalogs from motor manufacturers and the MotorMaster+ database, which is used to analyze motors and motor system efficiency.[6] MotorMaster+ contains list prices for manufacturers' motors and a performance database with information on over 17,000 motors from 18 manufacturers, including NEMA Premium motors. DOE's model database enables DOE to assess what is available in the market and to compare available equipment to

[6]Available at: http://www1.eere.energy.gov/industry/bestpractices/software_motormaster.html.

statutory definitions. DOE will use the resulting knowledge about equipment availability to evaluate how the market may respond to various standard levels (*e.g.*, consumers substituting motors that are not subject to regulation), as well as performance attributes of the various commercially available motor technologies.

3.2 Product Classes

As discussed earlier, EISA 2007 established energy conservation standards for four main categories of motors: general purpose electric motors (subtype I), general purpose electric motors (subtype II), fire pump motors, and NEMA Design B general purpose electric motors (from 200 hp through 500 hp). Within each category of motors, EISA 2007 set separate conservation standards by horsepower, enclosure, and pole configuration. These standards correspond to Table 12-12 of NEMA MG1-2006, "Full-Load Efficiencies for 60 hertz NEMA Premium Efficiency Electric Motors Rated 600 Volts or Less (Random Wound)," for subtype I motors; and NEMA Table 12-11 of NEMA MG1-2006, "Full-Load Efficiencies of Energy Efficient Motors," for subtype II, fire pump, and Design B motors. (42 U.S.C. 6313(b)(2))

In amending energy conservation standards, DOE divides covered product into classes when necessary. Products are divided by: (a) the type of energy used; (b) the capacity of the equipment; or (c) any other performance-related feature that justifies different standard levels, such as features affecting consumer utility. (42 U.S.C. 6295(q)) As a result of changes in EISA 2007, in particular the addition of general purpose subtype II motors to those covered by the term "electric motor," there are a large number of motor design features that DOE must consider in this rulemaking. In the following sections, DOE discusses a variety of design features that DOE is considering as product class setting criteria.

3.2.1 Horsepower Rating

Horsepower is a measurement directly related to the capacity of an electric motor to perform useful work. Additionally, it is generally true that efficiency scales with horsepower. In other words, a 50-horsepower motor is usually more efficient than a 10-horsepower motor. Horsepower is a critical performance attribute of an electric motor, and because there is a direct correlation between horsepower and efficiency, DOE initially proposes to use this as a criterion for distinguishing product classes.

3.2.2 Pole configuration

The number of poles in an induction motor determines the synchronous speed (i.e., revolutions per minute) of that motor. There is an inverse relationship between the number of poles and a motor's speed. As the number of poles increases from two to four to six to eight, the synchronous speed drops from 3,600 to 1,800 to 1,200 to 900 revolutions per minute. In addition, the number of poles has a direct impact on the motor's performance, and, based on a review of catalog data, also impacts motor efficiency. Consequently, DOE initially proposes to use the number of poles as a means of differentiating product classes.

3.2.3 Enclosure type

EISA 2007 prescribes separate energy conservation standards for open and enclosed electric motors. (42 U.S.C. 6313 (b)(1)) Motors manufactured with open construction allow a free interchange of air between the motor's interior and exterior. Motors with enclosed construction have no direct air interchange between the motor's interior and exterior and can be equipped with an internal fan for cooling (See NEMA MG1-2009, 1.26). Whether a motor is open or closed affects its utility. This difference also affects a motor's ability to dissipate heat and therefore efficiency. Therefore, DOE initially proposes to use a motor's enclosure type (open or enclosed) as a product class setting criterion.

3.2.4 National Electrical Manufacturers Association Design Letter

The National Electrical Manufacturers Association (NEMA) standards publication MG1 "Motors and Generators" defines a series of standard motor designs that are differentiated by variations in performance requirements (See NEMA MG1-2009 1.19.1). NEMA MG1 defines Design A, B, and C motors, and these are also covered by this rulemaking. These designs are categorized based on performance requirements for locked-rotor torque, startup torque, breakdown torque, and locked-rotor current, all of which ultimately affect a motor's utility and efficiency. Although NEMA Design A and NEMA Design B motors have slightly different locked-rotor current requirements, DOE has preliminarily decided that the effect that these differing requirements have on efficiency is not significant enough to warrant separate product classes. Congress recognized this when it held NEMA Design A and NEMA Design B motors to the same conservation standards prescribed by EPACT 1992 (Pub. L. No. 102-486) and again when standards were updated by EISA 2007 (Pub. L. No. 110–140). (42 U.S.C. 6311 (13)(A)) However, DOE does believe that the different torque requirements for NEMA Design C motors differ from the other motors significantly enough to warrant those motors being placed in a separate product class. Therefore, DOE initially proposes that NEMA Design A and B motors be grouped in the same product class while a separate product class be established for NEMA Design C motors.

3.2.5 Frame Type

EISA 2007 prescribed energy conservation standards for electric motors built with a U-frame, whereas previously only electric motors built with a T-frame were covered. (42 U.S.C 6311 (13)(B)) In general, a motor built in a U-frame is built with a larger "D" dimension, the distance from the centerline of the shaft to the bottom of the mounting feet, than a motor built in a T-frame, assuming the same combination of horsepower rating and number of poles. Therefore, for the same given horsepower and pole configuration combination, U-frame and T-frame motors may have different amounts of core material, which can in turn affect energy efficiency. The dimensional differences for a given horsepower and pole configuration would also constitute a change in utility as the larger U-frame motors will not fit in all applications as a T-frame motor. Under the assumption that all U-frame motors have larger cores (and therefore higher efficiency) than equivalent horsepower T-frame motors, DOE preliminarily proposes using frame type (U-frame vs. T-frame) as a product class setting criterion.

3.2.6 Vertical Solid Shaft Normal Thrust Motor

EISA 2007 also prescribed energy conservation standards for vertical solid shaft normal thrust motors as tested in a horizontal configuration. (42 U.S.C. 6311(13)(B)) These motors are most often found as NEMA Design A and NEMA Design B motors in a wide range of horsepower ratings and all four covered pole configurations. One of the major differences between these motors and normal general purpose motors is the mounting P-base. Additionally, as its name suggests, these motors operate while mounted vertically, but are tested while mounted horizontally. DOE believes a change in utility affecting performance, including performance related to efficiency, occurs when these motors are operated while mounted vertically but tested while mounted horizontally. Therefore, DOE initially proposes that whether a motor is designed to operate while mounted vertically be a product class setting criterion.

3.2.7 Close-Coupled Pump Motor

EISA 2007 prescribed energy conservation standards for close-coupled pump motors. (42 U.S.C. 6311(13)(B)) These motors can be purchased as NEMA Design A, B, or C motors, but are usually in two- or four-pole configurations. Close-coupled pump motors are frequently built with longer shafts than normal general purpose motors. Although these longer shafts may represent a separate utility, DOE does not believe that this change significantly affects the performance of the motors. Therefore, DOE initially proposes not using whether a motor is a close-coupled pump motor as a product class setting criterion.

3.2.8 Fire Pump Motors

EISA 2007 prescribed energy conservation standards for fire pump motors. (42 U.S.C. 6313 (b)(2)(B)) These motors are a subset of NEMA Design B motors as defined by National Fire Protection Association Standard (NFPA) 20, "Standard for the Installation of Stationary Pumps for Fire Protection" (2010). In addition to meeting the performance requirements for NEMA Design B motors, fire pump motors must also be able to continue running even if the motor is overheating or may be damaged due to continued operation. These additional requirements for fire pump motors constitute a change in utility that DOE believes could also affect performance and potentially efficiency. Therefore, DOE initially proposes establishing a separate product class for fire pump motors.

3.2.9 Voltage

EISA 2007 also expanded the range of voltages under which polyphase motors operate and are required to meet energy conservation standards. (42 U.S.C. 6311(13)(B)) In addition to the currently regulated polyphase motors operated at voltage ratings of 230 and 460 volts, EISA 2007 added all other polyphase motors operating at voltages less than 600 volts. Currently, electric motors designed to run on 230 volts or 460 volts are required to meet the same efficiency standards. DOE believes that this is the case because design voltage does not have a bearing on a motor's efficiency. That is not to say that DOE believes that a motor specifically designed to run on 460 volts will perform as well, in terms of efficiency, if run on 575 volts. Rather, DOE believes that a motor designed to run on 575 volts can perform as well (in terms of efficiency) as

an otherwise equivalent motor designed to run on 460 volts. Therefore, DOE proposes not using polyphase motor operating voltage as a product class setting criterion

3.2.10 Mounting Feet

DOE believes that whether an electric motor has attached mounting feet has no affect on a motor's efficiency potential. Mounting feet are external to the housing of the motor. DOE is unaware of any electrical performance characteristic that will change because a motor has feet. DOE does recognize that there is change in utility. However, that change alone is not sufficient to warrant a separate product class. Therefore, DOE preliminarily proposes not using whether a motor is footed or footless as a product class setting criterion.

Item 2 *DOE welcomes interested party comment on the proposed product class-setting criteria outlined for this rulemaking. In particular, DOE is interested in feedback regarding the continued aggregation of NEMA Design A and Design B motors, the disaggregation of NEMA Design C motors from Design A and B motors, and the disaggregation of U-Frame motors, T-Frame motors, and vertical mount motors. Finally, DOE is also interested in its proposal to not use close-coupled pump design as a product class setting criterion.*

3.3 Technology Assessment

The technology assessment focuses on understanding how energy is used by the product and what potential technology changes to the design and construction of an electric motor would reduce energy consumption. Measures that improve the energy efficiency of the product are called "technology options." These measures are based on existing technologies, as well as prototype designs and concepts. In consultation with interested parties, DOE will develop a list of technology options to consider in this rulemaking. Initially, this list will include all those options that are technologically feasible, including a max-tech design. In the screening analysis to follow, DOE will eliminate from consideration any technology options that fail to meet any of the four screening criteria: (1) technological feasibility; (2) practicability to manufacture, install, and service; (3) adverse impacts on product or equipment utility or availability; and (4) adverse impacts on health or safety (see section 4 for a more complete discussion).[7]

DOE is studying technology options that could be employed to improve the efficiency of the electric motors covered in this rulemaking. To this end, DOE is reviewing manufacturer catalogs, recent trade publications, and technical journals. DOE also intends to consult with technical experts who have worked on motor designs and applications. In addition, DOE conducted a rulemaking on small electric motors, and DOE believes that there is substantial overlap in terms of technology options between small electric motors and commercial and industrial electric motors that DOE can draw upon for this rulemaking.

[7] Technology options that pass all the screening criteria are called "design options," and, as such, they are analyzed in the engineering analysis (see section 5).

Below, DOE presents a set of technology options that were addressed in the small electric motors rulemaking that DOE believes could be used to improve the efficiency of electric motors as well. These technology options are categorized into four main categories: I^2R losses, core losses, friction and windage losses, and stray load losses.

3.3.1 Technology Options for I^2R Losses

I^2R is the expression of resistive loss in watts where I is measured current and R is resistance. I^2R losses occur when current flows through the copper windings in the stator and conductor bars in the rotor.. I^2R losses can be reduced by decreasing resistance to current flow in the electrical components of a motor. These losses are manifested as waste heat, which can shorten the service life of a motor.

Manufacturers use several methods to minimize the losses created by resistance to current flow. Most of these methods decrease resistance. There are different ways to decrease resistance, and different areas of the motor where this can be done effectively. The methods to reduce resistance in the conductor bars and stator windings are described as follows.

The resistance of a conductor is a function of both the resistivity and the geometric dimensions (*e.g.*, the cross-sectional area) of the material through which current flows. Resistivity is a physical characteristic that remains relatively constant for a given material, so changing the material type or manipulating the material's geometry (*e.g.*, copper wire diameter) are two approaches manufacturers employ to lower resistance.

Current flows through rotor conductor bars that are usually made of aluminum. One method of increasing the efficiency of the motor is to substitute copper bars for aluminum bars. Aluminum has a higher electrical resistivity (2.65×10^{-8} ohm-m) than copper (1.68×10^{-8} ohm-m). Copper is approximately 58 percent more conductive than aluminum, and changing from aluminum bars to copper bars would reduce associated I^2R losses in the rotor.

Manipulating the rotor's geometrical design is another way to reduce I^2R losses in the rotor. The conductor bars of the rotor are not straight from one end ring to another; instead, they are twisted or slightly skewed. By skewing the rotor bars, motor designers can reduce harmonics that add cusps to the speed-torque characteristics of the motor. Cusps in the speed-torque characteristics mean that the acceleration of the motor will not be completely smooth. The degree of skew matters, because reducing the skew will help reduce rotor resistance and reactance, thereby improving efficiency. However, overly reducing the skew may have adverse impacts on the speed-torque characteristics.

Increasing the cross-sectional area of the conductor bars is another way to change the rotor bar geometry and reduce resistance. Resistance is inversely proportional to the cross-sectional area of the material (*i.e.*, aluminum or copper) through which current is flowing. By increasing the cross-sectional area, resistance will decrease and current flow will increase.

The end ring is another area of the rotor that manufacturers may alter to reduce resistance. Current also flows through this area of the rotor. Increasing the size of the end ring can help decrease resistance and alleviate some of the I^2R losses.

When rotor resistance is lowered, rotor bar current is increased, resulting in an increase in electromagnetic forces. This may actually have some adverse impacts on the electric motor that would offset any gains in efficiency. In addition, when manufacturers increase the diameter of the rotor bars to lower rotor resistance, they remove steel from the lamination, and thus the magnetic circuit. The reduction in steel will increase magnetic saturation, which could offset any efficiency gains. Larger rotor bars may cause manufacturers to build new lamination tooling and add stack length because of increased magnetic saturation. Furthermore, changing the conductor bar shape could induce harmonics during the motor's operation. Odd harmonics, particularly the third harmonic, can create cusps in the speed-torque characteristics, which in turn disrupt motor acceleration.

I^2R losses also occur in the stator. Manufacturers may employ one of several design alterations to decrease these losses. Most of the design options involve increasing the amount of copper winding in the stator slots by using different gauges of copper wire, changing the slot sizes, and adjusting the length to diameter ratios. The use of larger (*i.e.*, numerically lower) wire gauges increases the efficiency of the motor because the larger cross-sectional area decreases the overall motor resistance. Increasing the stator's slot size may also enable manufacturers to increase the slot fill. Slot fill is the amount of copper wire inserted into a cross-sectional area relative to the total slot cross-sectional area. Depending on the number of poles in the motor, certain length-to-diameter ratios are better suited to balance the magnetic circuit.

A final way manufacturers reduce I^2R losses is by reducing the air gap between the stator and rotor. A smaller air gap decreases the loss of magnetomotive force that occurs across the air gap, requiring less current to drive the load, and reducing I^2R losses. The problem with this option is that smaller air gaps will require tighter tolerances for building motors. At some point a tighter tolerance would make it technically infeasible to manufacture motors according to specification. Based on discussions with manufacturers and small electric motor design engineers, DOE found that the smallest air gap practicable for small electric motors is 0.0125 inch.

Item 3 *DOE requests comment on the technology options for reducing I^2R losses. In particular, DOE understands that the 0.0125 small electric motor tolerance may be different for electric motors and seeks comment on what an appropriate air gap may be for electric motors covered by this rulemaking.*

3.3.2 Technology Options for Core Losses

Core losses occur in the steel components of a motor. These losses, like I^2R losses, manifest themselves as heat. Two electromagnetic phenomena cause core losses: hysteresis losses and eddy currents. Hysteresis losses result when magnetic domains resist reorientation to the alternating magnetic field (*i.e.*, 60 times per second, or 60 hertz). Eddy currents are physical currents that are induced in the steel laminations by the magnetic flux of the windings.

Manufacturers use several techniques to help reduce the effects of hysteresis and eddy current losses. One approach is simply adding additional steel to the rotor and stator (*i.e.*, increasing the "stack" length). This is one of the least costly and least invasive changes a manufacturer can use to increase motor efficiency. The extra steel laminations and increased stack height decrease flux density. This reduces hysteresis losses, but also changes motor performance. Adding stack length increases motor impedance, which is then reduced by removing turns of wire in the stator. The effect of increased stack length on monitored starting torque is also important. Increased stack length may reduce starting torque, potentially rendering the motor unable to start in certain applications. Finally, adding stack to the motor means the motor is also getting longer physically; therefore, geometrical constraints can become an issue as well.

Another technique for reducing core losses is using a higher quality, more efficient electrical steel in the core. Hysteresis losses are reduced using this technique because the magnetic permeability improves and grain size increases, reducing the magnetic domain resistance. Eddy currents are reduced because the resistivity of the laminations is higher, reducing the magnitude of the currents. In studying the techniques used to reduce steel losses, DOE considered two types of materials: conventional silicon steel and so-called "exotic" steels, which contain a relatively high percentage of boron or cobalt.

Conventional steels are commonly used in electric motors manufactured today. There are three types of steel that DOE considers "conventional:" cold-rolled magnetic laminations (CRML), fully processed non-oriented electrical steel, and semi-processed non-oriented electrical steel. Each steel type is sold in a range of grades. Generally, as the grade number goes down, so does the amount of loss associated with the steel (*i.e.*, watts of loss per pound of steel). The induction level also drops, causing the need for increased stack length. CRML steels are the most commonly used conventional steel, but are also the least efficient. The fully processed steels do not require annealing after being punched and assembled, and are available in a range of steel grades from M56 through M15.[8] Semi-processed electrical steels are designed for annealing after punching and assembly, but they have more limited availability.[9]

The exotic steels are not generally manufactured for use specifically in the electric motors covered in this rulemaking. These steels include vanadium permendur and other alloyed steels containing a high percentage of boron or cobalt. These steels offer a lower loss level than the best electrical steels, but are more expensive per pound. In addition, these steels can present manufacturing challenges because they come in non-standard thicknesses that are difficult to manufacture.

Manufacturers also reduce core losses by using thinner steel laminations. Using thinner laminations decreases the cross-sectional area through which the eddy currents are produced and reduces the magnitude of the eddy currents. The resultant reduction in current losses reduces heat generation and improves efficiency. However, this design change does affect the manufacturing

[8] Lower "M" grades of steel denote lower losses, thus M15 has fewer losses per pound of steel than M56.

[9] AK Steel Corporation. *Product Data Bulletin: Selection of Electrical Steels for Magnetic Cores*, West Chester, OH (July 2007).

process. As laminations become thinner, more laminations are needed for the same stack height, and the time required for punching and assembly increases.

Manufacturers may also reduce eddy currents by using improved insulating coatings between the steel laminations. Improved coatings increase the resistance between the steel laminations, which makes it more difficult for eddy currents to flow from lamination to lamination.

Annealing the core steel is another technique manufacturers use to reduce hysteresis losses. Annealing is a heating process that alters the grain structure of the steel and alleviates any stresses introduced during punching and assembly. After being annealed, the material becomes much easier to magnetize; as a result, the magnetic domains reorient more easily. Manufacturers incur more cost when they perform additional annealing because they are adding another step to the manufacturing process, and that increases production time. Annealing equipment also requires a large capital investment.

Item 4 *DOE requests comment on the technology options for reducing core losses. In particular, DOE seeks comment on the most appropriate steels, both "conventional" and "exotic," that it should consider in its analysis.*

3.3.3 Plastic Bonded Iron Powder

Recently, DOE became aware of a new technology that Lund University researchers in Sweden developed: the production of magnetic components for electric motors from plastic bonded iron powder (PBIP). The technology has the potential to cut production costs by 50 percent while doubling motor output.

The method uses two main ingredients: metal powder and plastics. Combining the ingredients creates a material with low conductivity and high permeability. The metal particles are surrounded by an insulating plastic, which prevents electric current from developing in the material, essentially eliminating losses in the core due to eddy currents. Properties of PBIP can differ depending on how they are manufactured. If the metal particles are compacted too closely and begin to touch, the material's electrical conductivity will increase, counteracting one of its most important energy efficiency features.

Another advantage of PBIP is that the number of steps required to manufacture a rotor and stator is reduced from roughly 60 to just a few. PBIP can also be used to build an inductor. During manufacture, the plastic and metal are molded together using a centrifugal force. During that process, the inductor core consisting of PBIP and pre-wound windings are baked into the core. This inductor is then used as a filter for grid power applications. The filter reduces the use of cooling equipment in the motor design.[10]

[10] H. Horrdin & E. Olsson, *Technology Shifts in Power Electronics and Electric Motors for Hybrid Electric Vehicles: A Study of Silicon Carbide and Iron Powder Materials.* Chalmers University of Technology, Göteborg, Sweden (2007).

Item 5 *DOE seeks any information regarding recent developments of plastic iron powder technology and comments on whether DOE should consider it in its analysis for electric motors.*

3.3.4 Technology Options for Friction and Windage Losses

Motor bearing friction and an imperfect cooling fan system create what is called "friction and windage losses" in AC induction motors. These losses also add heat to the motor's system and decrease the motor's efficiency.

To decrease the losses caused by motor bearings, manufacturers can change the bearings or bearing lubricant. Less friction, and thus less heat, is produced when manufacturers use a better bearing structure or bearing lubricant, but manufacturers must also consider issues such as temperature rating and speed.

Another way to reduce heat in an induction motor is to use a better cooling system. Changing the fan or adding baffles to the current fan can help reduce heat and losses. Baffles help redirect airflow through the motor, creating better circulation and a cooler motor overall. A motor that uses a well-designed air cooling system should run more efficiently. However, some manufacturers choose to use the same cooling system for a range of horsepower ratings. This means that the cooling system designed to operate on a larger motor, when implemented on a smaller motor, may be larger than necessary to properly cool the motor, resulting in more losses than necessary.

Item 6 *DOE requests comment on the technology options for reducing friction and windage losses.*

3.3.5 Technology Options for Stray-Load Losses

Any losses that are otherwise unaccounted for and not attributed to I^2R losses, steel losses, or frictional and windage losses are considered stray-load losses. DOE is not aware of any specific techniques manufacturers use to reduce stray-load losses. General process changes to the manufacturing of rotors and stators could somewhat reduce these losses.

3.3.6 Summary of the Technology Options Under Consideration

Table 3.3.1 summarizes the technology options discussed in this framework technology assessment and those that DOE is preliminarily considering for this rulemaking. The options that pass all four screening criteria will be considered "design options" and will be used in the engineering analysis.

Table 3.3.1 Summary of Technology Options for Improving Efficiency

Type of Loss to Reduce	Technology Option Applied
I^2R Losses	Use copper die-cast rotor cage
	Remove skew on conductor cage
	Increase cross-sectional area of rotor conductor bars
	Increase end ring size
	Changing gauges of copper wire in stator
	Manipulate stator slot size
	Decrease the radial air gap
Core Losses	Improve grades of electrical steel
	Use thinner steel laminations
	Anneal steel laminations
	Add stack height (*i.e.*, length, add electrical steel laminations)
	Use high-efficiency lamination materials
	Use plastic bonded iron powder
Friction and Windage Losses	Use better bearings and lubricant
	Install a more efficient cooling system

DOE is aware that there are certain technology options that have design trade-offs that can increase losses in some areas while reducing losses in other areas. The precise impacts on electric motor cost and efficiency will depend on how the designer makes tradeoffs between improved performance due to improved materials or design and maintaining the motor performance. For example, the I^2R of the rotor is one of the main sources of energy loss in the rotor. Technology options that may reduce the I^2R loss in the rotor may increase electrical conductivity losses in the stator.

Item 7 *DOE welcomes comment on the technology options identified in this section. DOE welcomes comment on whether there are other technology options that it should also consider.*

4 SCREENING ANALYSIS

The purpose of the screening analysis is to screen out technology options (established in the market and technology assessment) that DOE will not consider in the rulemaking for electric motors. Through its own research and in consultation with interested parties, DOE will develop a list of candidate design options for consideration. The initial list will include all candidate design options considered to be technologically feasible.

Thereafter, DOE will review each candidate design option in light of the following four criteria, as provided in section 4(a)(4) and 5(b) of the Process Rule,[11] and tailored to the current rulemaking:

1. *Technological feasibility.* If DOE determines that a design option is not incorporated in commercially available motors or in working prototypes, then it will not give further consideration to that design option.

2. *Practicability to manufacture, install, and service.* If DOE determines that mass production or reliable installation and servicing of a design option could not be achieved on the scale necessary to serve the relevant market by the time of the compliance date of the standard, then it will not give further consideration to that design option.

3. *Adverse impacts on product or equipment utility or availability.* If DOE determines that a design option has significant adverse impacts on the utility of the motor to significant subgroups of consumers, or results in the unavailability of any covered motor with performance characteristics (including reliability), features, sizes, capacities, and volumes that are substantially the same as motors generally available in the United States at the time, it will not give further consideration to that design option.

4. *Adverse impacts on health or safety.* If DOE determines that a design option will have significant adverse impacts on health or safety, it will not give further consideration to that design option.

DOE will fully document its reasons for eliminating any technology options during the screening analysis, and will publish this documentation for interested party review and comment as part of the preliminary analysis.

Item 8 *DOE welcomes comments on how the above four screening criteria might apply to the technology options discussed in the market and technology assessment.*

5 ENGINEERING ANALYSIS

After conducting the screening analysis described above, DOE will perform an engineering analysis based on the remaining design options that improve motor efficiency. This section provides an overview of the engineering analysis (section 5.1); discusses DOE's proposed approach to the engineering analysis, including scaling (section 5.2.4); and addresses proprietary designs (section 5.2.3), and regulatory burdens that might affect the engineering analysis (section 5.3).

5.1 Engineering Analysis Overview

The purpose of the engineering analysis is to determine the relationship between the manufacturer's selling price and efficiency for electric motors. In determining the price-efficiency relationship, DOE will estimate the increase in the manufacturer selling price associated with design changes that increase the efficiency of motors relative to the baseline

[11] 10 CFR Part 430, Subpart C, Appendix A.

models (which meet the lowest energy efficiency levels currently sold on the market). DOE will develop cost estimates for the engineering analysis (which it will also use in section 12, the manufacturer impact analysis) from detailed data on the incremental costs of changes in material, labor, and overhead from the baseline.

To start, DOE will develop separate engineering analyses for each of the baseline models it chooses to analyze. DOE intends to use motor teardowns and efficiency tests in accordance with DOE's test procedure for electric motors to develop its own cost-efficiency relationships for the motors analyzed. As previously mentioned, due to the large number of product classes considered in this standard rulemaking, DOE plans to select a smaller subset of representative product classes to analyze. Subsequently, DOE will scale results from these representative product classes to the remaining product classes.

DOE seeks input on the methods and approaches used by manufacturers to improve the efficiency of motors. In addition, DOE intends to model the highest efficiency (*i.e.,* the "max-tech" model) that is technologically feasible within each product class by using a software package. DOE's engineering analysis will document the design changes and costs associated with improving motor efficiency from the baseline through the max-tech model. This will include considering improved electrical steel for the stator and rotor, improved electrical conductors, and so on. As each of these design options are added, the manufacturer's cost generally increases and the motor's efficiency (and performance) improves.

Item 9 *DOE welcomes input from interested parties on a software package that would be appropriate for use in developing the max-tech models for each electric motor analyzed.*

5.2 Engineering Analysis Approach

For the engineering analysis, DOE will examine incremental increases in the manufacturer selling price associated with increases in motor efficiency. For the preliminary analysis, DOE intends to utilize its database of electric motors available in the market to categorize relationships between efficiency and some design options. DOE will also use this information to select product classes that are representative of the population of product classes. DOE will then focus its analyses on these representative units.

5.2.1 Baseline Models

Once DOE establishes product classes, it will select baseline models as reference points for each product class against which it can measure changes in efficiency and cost resulting from potential energy conservation standards. The baseline model represents the characteristics of the lowest efficiency, most typical motor sold in a given product class. DOE will select baseline models that are in compliance with the applicable electric motor energy conservation standards that were set by EISA 2007 and go into effect in December 2010. Accordingly, DOE has determined that a baseline model should encompass motor features and performance characteristics such as motor design, horsepower ratings, pole configuration, and enclosure type. DOE will not fully define all the detailed characteristics of the proposed baseline models until it

receives comments from interested parties and can conduct further analysis. However, DOE has done some preliminary research to identify representative product classes from which it will select its baseline models.

DOE hopes to identify representative product classes that could be used to analyze all sets of product classes identified in section 3.2. To do so, DOE examined the database used by its MotorMaster+ software program. DOE developed MotorMaster+ to function as an efficiency motor selection and management tool that supports motor and motor systems planning by identifying the most efficient action for a given motor repair or purchase decision.[12] The software utilizes a database that lists over 17,000 different motor models from numerous motor manufacturers. Motor models from nearly all of DOE's electric motors product classes are in this database. After preliminary examination of this database and consideration of its newly proposed product class setting criteria, DOE has decided to propose representative units that it believes will be appropriate to analyze in the preliminary analysis. DOE proposes to analyze one general purpose NEMA Design B motor, one NEMA Design C motor, one U-frame motor, one vertical shaft normal thrust motor, and one closed-coupled pump motor. DOE believes that because fire pump motors are a specific subset of NEMA Design B motors, analysis of a separate representative product class for those motors is not needed. DOE hopes to further define the proposed representative product classes, and representative units within those classes, using comments from interested parties on the most appropriate combinations of horsepower rating, motor enclosure, and pole configuration.

Item 10 *DOE welcomes comment on whether it has identified the representative product classes and representative units appropriately. DOE also welcomes comment on the appropriate horsepower ratings, pole configurations, and motor enclosures to analyze for each of the proposed motor designs.*

5.2.2 Methodology

DOE plans to purchase, test, and teardown selected motors within each representative product class. The motors will be tested for efficiency according to the appropriate DOE test procedures for electric motors. (10 CFR 431.16) To determine the price of the motor, DOE will have a professional laboratory disassemble and inventory the motors to derive the material and labor costs. An important input to the motor cost includes prices for materials such as the electrical steel, copper windings, and aluminum rotor bar/end rings. A materials price analysis will be based on a five-year average of typical costs when these materials are purchased in volume. DOE will seek materials pricing information from current, publicly available data.

DOE may supplement the findings from its tests and teardowns through: (1) a review of data collected from manufacturers about prices, efficiencies, and other features of various models of electric motors, and (2) interviews with manufacturers about the techniques and associated costs used to improve efficiency. In addition, DOE will use the cost data generated by the engineering analysis in the manufacturer impact analysis (see section 12). If possible, DOE will

[12] Available at: http://www1.eere.energy.gov/industry/bestpractices/software_motormaster.html.

then aggregate the cost numbers by weighing individual data points by company-level sales volumes for each product class.

To be useful in the manufacturer impact analysis, manufacturer cost information should reflect the variability in baseline models, design strategies, and cost structures that exist among manufacturers. If necessary, DOE will qualify any aggregated cost-efficiency data. Information obtained through follow-ups with manufacturers will assist this effort. These confidential interviews will provide a deeper understanding of the various combinations of technologies used to increase motor efficiency, as well as their associated manufacturing costs.

DOE will estimate the contribution of the depreciation of conversion capital expenditures to the incremental overhead. During the confidential interviews with manufacturers, DOE will gather information about the capital expenditures needed to increase the efficiency of baseline models to various efficiency levels (*i.e.*, conversion expenditures by efficiency). DOE will also gather information about the depreciation method(s) used to expense the conversion expenditures.

The approach proposed above will enable DOE to characterize the cost-efficiency relationship for motors across the entire efficiency range for all product classes. As explained above, DOE will maintain the confidentiality of proprietary data while allowing the public to examine the cost and design assumptions that underlie the cost-efficiency estimates.

DOE then plans to apply markups to convert manufacturer production costs to manufacturer selling prices. DOE intends to estimate manufacturer markups from publicly available financial information (*e.g.*, Securities and Exchange Commission 10-K reports).

Item 11 *For each product class, DOE welcomes interested party comment on methods and approaches employed to improve the efficiency of the motors, including the max-tech model. Detailed information on the motor performance and the incremental manufacturing costs (e.g., material costs,[13] labor costs,[14] overhead costs[15] (excluding depreciation), building conversion capital expenditures, tooling/equipment conversion capital expenditures associated with more efficient designs, research and development (R&D) expenses, and marketing expenses) would be useful.*

Item 12 *DOE welcomes comment on the markup approach proposed for developing estimates of manufacturer selling prices.*

Item 13 *DOE welcomes comment on the above-described approach to determining the relationship between manufacturer selling price and motor efficiency.*

5.2.3 Proprietary Designs

DOE will consider in its engineering and economic analyses all design options that are commercially available or present in a working prototype, including proprietary designs. DOE will consider a proprietary design in the subsequent analyses only if it is not a unique path to a given motor efficiency level. If the proprietary design is the only approach available to achieve a given efficiency level, DOE will reject the efficiency level from further analysis. Furthermore, DOE is sensitive to manufacturer concerns regarding proprietary designs and will take appropriate steps to maintain the confidentiality of any proprietary data that manufacturers submit. This information will provide input to the competitive impacts assessment and other economic analyses.

Item 14 *DOE welcomes comment on whether there are proprietary designs it should consider for any of the motor designs under consideration in this rulemaking and, if so, how DOE should acquire the cost data necessary for evaluating these designs.*

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[13] Direct material costs are the costs of raw materials such as steel, copper, and insulation, and also include scrap metal that can be traced to final or end equipment. Direct material costs do not include indirect material costs which are attributed to supplies that may be used in the production process, but are not assigned to final pieces of equipment (*e.g.*, lubricating oil for production machinery).

[14] Labor costs are the earnings of workers who assemble parts into a finished good or operate machines in the production process. Direct labor costs include the fringe benefits of direct laborers such as group health care, as well as overtime pay. Direct labor costs do not include indirect labor, which is defined as the earnings of employees who do not work directly in assembling a piece of equipment—such as supervisors, janitors, stockroom personnel, inspectors, and forklift operators.

[15] Factory overhead excludes depreciation, but includes indirect labor, downtime, set-up costs, indirect material, expendable tools, maintenance, property taxes, insurance on assets, and utility costs. Factory overhead does not include selling, general, and administrative costs (SG&A), R&D, interest, or profit (which DOE accounts for separately).

5.2.4 **Scaling**

Once DOE has identified cost-efficiency relationships for the representative units that it selects, it will appropriately scale the engineering analysis results of its representative product class' findings to the other product classes that were not directly analyzed. To scale the findings from one product class to another, DOE will identify relationships between the product classes through a characterization of the current market. DOE proposes to develop potential scaling relationships for electric motors by creating a model that describes efficiency as a function of a motor's rated horsepower. DOE intends to do this by examining the energy conservation standards for electric motors prescribed by EISA 2007. This includes NEMA Premium levels for general purpose subtype I motors and the EPACT 1992 levels adopted for general purpose subtype II motors. These standards, mandated by EISA 2007, illustrate how losses and efficiency vary according to horsepower rating, pole configuration, and motor enclosure.

For general purpose subtype I motors of open construction, the NEMA Premium standards shown in NEMA MG 1-2006 in Table 12-12 are minimum nominal full load efficiency levels. Table 12-12 lists the efficiency standards for motors ranging in horsepower from 1 to 200 horsepower in two-, four-, and six-pole configurations, as well as with open and enclosed constructions. To determine efficiency trends, DOE converted these efficiency standards into motor losses using the equation (1/efficiency)-1, which is a commonly used and widely accepted equation in industry to calculate motor losses as a function of efficiency. The resulting motor losses were then logarithmically plotted versus horsepower as depicted in Figure 5.1.

When plotted on logarithmic axes, DOE observed that as horsepower increases, motor losses decrease following a power law function, as shown in Figure 5.1. The power law for this particular function shows that motor losses scale according to a negative 0.27 exponent as horsepower increases. Each one of the lines shown in Figure 5.1 is a representation of how motor losses change with respect to horsepower for open motors with one of three pole configurations—two, four, or six. The relationships for enclosed motors can be illustrated with three similar lines and equations. When describing motors with different combinations of attributes (i.e. two poles versus six poles) the exponent of negative 0.27 varies slightly, but DOE believes 0.27 is a reasonable approximation and is appropriate for all six combinations of enclosure and pole configuration.

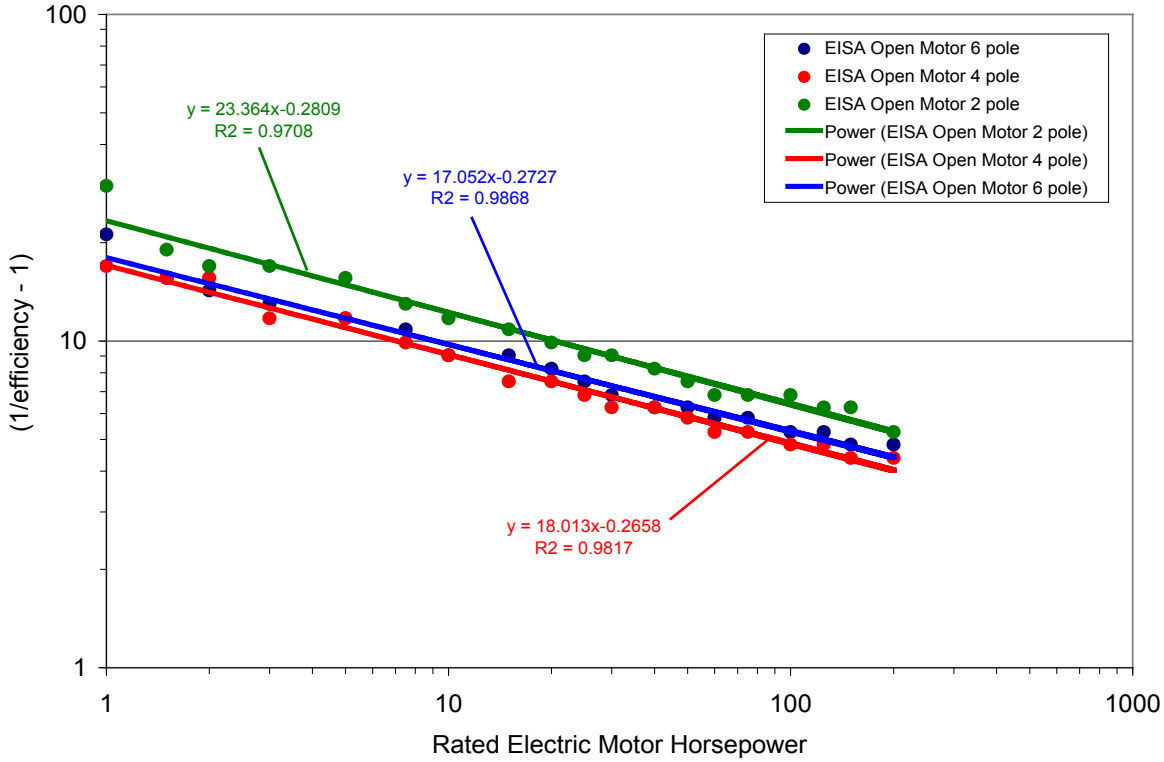

Figure 5.1 NEMA Premium Motor Losses as a Function of Horsepower Rating for Open Motors

DOE proposes to model motor losses as a function of horsepower using equations with the following general formula: $Motor\ Losses(hp) = C \times hp^{-.27}$, where C is a constant that is different for each combination of pole configuration and enclosure type. For example, in Figure 5.1, C for two-pole open motors is equal to 23.4, whereas C for four-pole open motors is equal to 18.0. DOE can manipulate these motor loss equations to scale the motor losses of the representative units analyzed to all other combinations of horsepower rating, pole configuration, and enclosure. It is the relative change in the value of C for each motor loss equation that dictates how motor losses, and thus efficiency, are scaled for a change in pole configuration, motor enclosure, or both. The exponent of negative 0.27 dictates how efficiency changes as horsepower rating is changed.

When DOE examined and compared the efficiency standards for each basic model of open motor with the same basic model of enclosed motor, for example, a 30 horsepower, four-pole open motor with a 30 horsepower, four-pole enclosed motor, it noted that the energy efficiency standard was not necessarily the same for both, in this case 94.1 percent efficient versus 93.6 percent efficiency, respectively. In other words, for some combinations of horsepower ratings and number of poles, the efficiency standards for open versus enclosed motors are higher, for others it is lower, and for others it is the same. For pole configurations, the relative efficiency levels between two-, four-, and six-pole motors are much more consistent. Therefore, DOE believes it may be more prudent to determine the efficiency standards for all combinations of horsepower ratings and pole configurations for open (or enclosed motors) by using the aforementioned equations. Once DOE has a set of efficiencies (or motor losses) for

open motors (or enclosed) in all combinations of horsepower rating and pole configuration, those values could be multiplied by the ratio of the current efficiency standards (or corresponding motor losses) for open and enclosed motors for the corresponding combinations of horsepower rating and pole configuration.

Item 15 *DOE welcomes comment from interested parties on the best methodology for scaling from the representative product classes to the remaining product classes, including the proposed methodology of using a power law function and an industry-accepted equation for motor losses to model the efficiency relationships established by EISA 2007.*

Item 16 *DOE also welcomes comment from interested parties on the best approach for scaling from open motors to enclosed motors (or vice versa).*

5.3 Outside Regulatory Changes Affecting the Engineering Analysis

In conducting an engineering analysis, DOE takes into consideration the effects of regulatory changes outside DOE's statutory energy conservation standards rulemaking process that can impact the manufacturers of the covered equipment. Some regulatory changes can also affect the efficiency or energy consumption of the motors covered under this rulemaking. DOE will attempt to identify all such outside engineering issues that could impact the engineering analysis. The consideration of these issues is closely related to the cumulative regulatory burden assessment that DOE will carry out as part of the manufacturer impact analysis.

Item 17 *DOE welcomes comment on whether there are outside regulatory changes that DOE should consider in its engineering analysis of electric motors.*

6 ENERGY USE ANALYSIS

The purpose of the energy-use analysis is to identify how products and equipment are used by consumers, and thereby determine the energy savings potential of energy efficiency improvements. The unit energy consumption calculated in the energy use analysis chapter is intended to represent the typical annual energy consumption of motors in the field.

The engineering analysis (section 5) will report motor efficiency based on the test procedures prescribed under 10 CFR 431.16. These motor efficiency values measured according to the test procedures provide standardized results that serve as the basis for comparing the performance of different motors used under the same conditions. Actual usage in the field may vary depending on the conditions in which the products and equipment driven by the motor are operated.

For electric motors, the end-use load is the mechanical work that is performed by the equipment, which varies over time and with different applications. The energy use of the motor equals the end-use load plus any energy losses associated with motor operation. For the motors

covered in this rulemaking, this analysis will focus on how end-users install and operate these motors and how motor operation and its associated losses vary over time with different applications (*e.g.*, fans, blowers, pumps, compressors, and conveyors).

DOE intends this analysis to capture and represent the typical energy consumption in the field. This analysis is an input to the LCC (section 8) and national impact analyses (section 10). This usage profile will enable DOE to calculate the LCC and payback period of more efficient motor technologies relative to the baseline motor.

Motor loading is the fraction of motor capacity that is utilized on average. This factor is important for determining which motor designs will deliver a specified efficiency. In addition, DOE intends to develop a model of motor loads to use when determining average and peak load levels for various electric motor designs as part of the energy use analysis. DOE is also interested in evaluating broader motors system effects on the field energy use of motors (*e.g.*, the extent and impact of the use of adjustable speed drives in different applications).

DOE will also determine the reactive power demand for each product class at different loading points and efficiency levels. Reactive power is power that is reflected back to the electrical system by a change in the phase of alternating current power. Although reactive power does not impact the site energy use associated with operating motors, it is a necessary input for the LCC.

Item 18 *DOE seeks to identify and obtain detailed data on the typical applications and end-use profiles for the motors considered in this rulemaking. If the range of energy use determined for each product class is large enough, DOE will conduct a sensitivity analysis to determine how high and low estimates of energy use might impact the economic feasibility of any amended energy conservation standards. DOE welcomes recommendations on sources of data that would provide end-use operating profiles for each of the product classes covered under this rulemaking.*

Item 19 *DOE welcomes comment on whether the end-use operating profiles are different for each of the product classes covered under this rulemaking, as well as how the profiles may be different.*

Item 20 *DOE welcomes comments regarding motor repair practices and their impact on motor energy use.*

Item 21 *DOE welcomes comment on other end-use issues that could impact the energy use analysis.*

7 MARKUPS FOR EQUIPMENT PRICE DETERMINATION

After DOE applies manufacturer markups to convert manufacturer production costs to manufacturer selling price in the engineering analysis described in section 5 above, DOE uses distribution channel markups to convert the manufacturer selling price to customer (retail) prices.

DOE then uses the customer (retail) prices calculated from these markups in the LCC and payback period analysis, and in the national impact analysis. Retail prices are needed for the baseline efficiency level and all other efficiency levels under consideration. To validate these markups, DOE will attempt to collect data on existing prices in the market either by purchasing large data sets or by downloading data from distributor internet sites.

Before it can develop markup information, DOE must first identify distribution channels (*i.e.*, how a motor is distributed from the manufacturer to the consumer). Once it establishes proper distribution channels for each of the product classes, DOE will rely on economic census data from the U.S. Census Bureau, as well as input from the electric motor industry and motor experts, to develop an understanding of the markups applied as a motor moves from the manufacturer to the consumer.

Because DOE expects to generate a range of price estimates, it plans to describe new retail prices within a range of uncertainty. If the range of retail prices for each product class is large enough, DOE will conduct a sensitivity analysis to determine how high and low estimates of retail price might impact the economic feasibility of any potential amended energy conservation standard.

Item 22 *DOE welcomes comment on the distribution chain for electric motors, the key stakeholders in those distribution chains, the typical markups applied by those stakeholders, and the overall markup from manufacturer selling price to consumer retail price.*

8 LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

The effects of more stringent energy conservation standards on consumers include a change in operating expense (usually decreased) and a change in purchase price (usually increased). DOE analyzes the net effect on customers by calculating the LCC and payback period using the engineering performance data (section 5), the energy-use and end-use load characterization data (section 6), and the equipment retail prices (section 7). Inputs to the LCC calculation include the cost to the customer of the installed equipment (purchase price plus installation cost), operating expenses (energy expenses and, if applicable, repair costs and maintenance costs), the lifetime of the equipment or other defined period of analysis, and a discount rate.

For the preliminary analysis, DOE will conduct the LCC analysis using values to reflect conditions in the field for equipment retail price and life, energy prices (including the price of reactive power), energy usage (including reactive power demand), and discount rates. If some inputs to the determination of consumer LCC and PBP are either variable or uncertain, DOE will use probability distributions to characterize the inputs. If DOE determines that there is significant variability in any of the above inputs, it will conduct sensitivity analyses to determine how the LCC and payback period are impacted by high and low estimates for each of the inputs. The detailed impact calculation, which DOE will conduct after the preliminary analysis, may include an assessment of impacts on subgroups of customers, as described in section 11.

Based on the results of the LCC analysis, DOE will select candidate standard levels (CSLs) for the preliminary analysis. The range of CSLs typically will include the motor efficiency level with the lowest LCC, the highest efficiency level that is technologically feasible, and other intermediate levels that DOE will determine to incorporate noteworthy technologies or fill in large gaps between other efficiency levels considered.

For the NOPR, DOE will carefully review all of the comments it receives on the preliminary LCC analysis, make any necessary revisions to the analysis, and evaluate additional parameters not included in the preliminary analysis, if necessary.

For the LCC and payback period analysis, DOE will need to determine input values for several variables. Two of these variables, energy use characterization and purchase prices, were discussed in sections 6 and 7, respectively. The following sections discuss the methodologies DOE plans to use to develop energy prices, discount rates, maintenance/repair/installation costs, and motor lifetimes.

8.1 Energy Prices

For customers who use electric motors, DOE will survey commercial and industrial electricity tariffs[16] as a means for establishing marginal electricity prices.

DOE will also use data from the Commercial Building Energy Consumption Survey[17] conducted by the Energy Information Administration (EIA) to estimate building electricity use characteristics that impact electricity prices. If the tariff survey and EIA data demonstrate a large variability in electricity prices, DOE will conduct a sensitivity analysis to determine how high and low electricity price estimates might impact the economic feasibility of any amended energy conservation standards. DOE will use projections of national average energy prices for commercial and industrial customers—principally from EIA's *Annual Energy Outlook* (*AEO*) from the most recent year available—to estimate future energy prices in its LCC analysis. In order to account for the expenses due to reactive power demand (section 6), DOE also intends to survey reactive power prices, principally using data from the EIA.

Item 23 *DOE welcomes input on the proposed methodology for estimating current and future electricity prices.*

[16] "Energy tariffs" are the rules for calculating energy bills. DOE maintains a database of hundreds of tariffs that can be used to calculate incremental energy bill impacts from energy savings. See: K. Coughlin, R. White, C. Bolduc, D. Fisher, & G. Rosenquist, *The Tariff Analysis Project: A database and analysis platform for electricity tariffs,* Lawrence Berkeley National Laboratory, Berkeley, CA, LBNL-55680 (2006) (available at http://ees.ead.lbl.gov/bibliography/the_tariff_analysis_proje); and K. Coughlin, C. Bolduc, R. Van Buskirk, G. Rosenquist & J. E. McMahon, *Tariff-based Analysis of Commercial Building Electricity Prices,* Lawrence Berkeley National Laboratory: Berkeley, CA, LBNL-55551 (2008) (available at: http://escholarship.org/uc/item/9dv1m729.pdf).

[17] Available at: http://www.eia.doe.gov/emeu/cbecs/.

8.2 Life-Cycle Cost Discount Rates

The calculation of customer LCC requires the use of an appropriate discount rate for those commercial or industrial companies that purchase electric motors. DOE will derive the discount rates for these commercial and industrial customers by estimating the capital costs for companies that purchase electric motors. The cost of capital is commonly used to estimate the present value of cash flows to be derived from a typical company project or investment. Most companies use both debt and equity capital to fund investments, so the cost of capital is the weighted-average cost of equity and debt financing. This corporate finance approach is referred to as the weighted-average cost of capital.

DOE will publish the discount rates and associated documentation on the derivation of these discount rates in the preliminary analysis. It will invite stakeholders to comment specifically on the issue of customer discount rates during the preliminary comment period.

Item 24 *DOE welcomes input on the proposed approaches for estimating discount rates for customers of motors covered under this rulemaking.*

8.3 Maintenance, Repair, and Installation Costs

Typically, DOE will take into consideration any expected changes to maintenance, repair, and installation costs for the equipment covered in a rulemaking. Often, small incremental changes in equipment efficiency would incur little or no change in repair and maintenance costs over baseline equipment. For equipment with significant energy efficiency improvements over the baseline, there may be increased repair and maintenance costs because such equipment is more likely to incorporate technologies that are not widely available. For electric motors, DOE expects that maintenance and repair costs will not change with increased efficiency. DOE invites comment on how repair costs may change for more efficient motors that may be more expensive than motors currently in the market. DOE also invites comment on repair practices (such as motor rewinding), how they may change for more efficient motors, and how motor energy use may change following repair. With regard to installation costs, DOE is aware that there is variability in the costs for commercial and industrial sector motor installations. However, DOE does not believe that existing installation practices would necessarily change under an amended energy conservation standard. DOE does recognize that larger, more efficient motors may be more difficult and expensive to install in constrained spaces or configurations.

Item 25 *DOE welcomes comment on whether and how to develop maintenance, repair, and installation costs for electric motors. Specifically, DOE invites comment on how efficiency requirements may affect the ability of motor designs to fit in constrained spaces and configurations. DOE also invites comment on changes in repair practices that may accompany more efficient motors.*

8.4 Motor Lifetimes

DOE will use information from catalogs and various literature sources, and input from manufacturers and other stakeholders, to establish motor lifetimes for use in the LCC and subsequent analyses. DOE may consider correlation between motor lifetime and loading and duty factor, if quantitative evidence is found that loading and duty factors in the field affect motor lifetimes.

Based on consideration of the comments received for the preliminary analysis, DOE will make necessary changes to the analysis. These changes will be reflected in the documentation of the NOPR.

Item 26 *DOE welcomes comment on appropriate motor lifetimes for the product classes covered in this rulemaking, as well as data regarding correlation between motor end-use patterns and motor lifetime.*

9 SHIPMENTS ANALYSIS

DOE requires shipment forecasts to calculate the national impacts of standards on energy consumption (section 10), NPV (section 10), and future manufacturer cash flows (section 12). DOE plans to develop shipments forecasts based on an analysis of key market drivers for the covered motors.

9.1 Base Case Forecast

To evaluate the various impacts of standards, DOE develops an energy conservation and energy costs base case forecast against which to compare forecasts for higher efficiency levels (standards case). The base case forecast depicts what will happen to energy consumption and energy costs over time if DOE does not adopt energy conservation standards for the motors covered under this rulemaking (as detailed in section 10). In determining the base case forecast, DOE will consider historical shipments, the mix of motor efficiencies currently sold, and how that mix might change over time in absence of an amended standard. For these purposes, DOE needs data on historical equipment shipments and market shares of the different efficiency levels offered in each product class.

To that end, DOE seeks data on historical shipments for general purpose electric motors (subtype I and subtype II), including (but not limited to) NEMA Design A, B, or C motors in T- or U-frames, with or without mounting feet. DOE is considering manufacturers and industry organizations as potential sources of such information. Alternatively, DOE is considering purchasing national market reports, examining data collected in national energy and motor use surveys, or extrapolating historical motor sales data from the United States Bureau of Census. The United States Bureau of Census publishes limited information on the quantity and dollar-value of equipment shipments. However, the Census data does not disaggregate the motors according to motor design or energy conservation standard product class and ceased publication of motor data after publishing data for the year 2003.

DOE hopes to collect shipment data within each product class, as well as market share efficiency data (*i.e.*, data on the distribution of equipment shipments by motor efficiency), if applicable, for each product class. DOE recognizes that this information may be difficult to collect, and may, therefore, consider methods other than shipment and market share efficiency data to estimate the efficiency distribution in the market. For instance, if market share efficiency data are not available, DOE may develop, as a proxy, efficiency distributions based on available models and information from motor experts.

Item 27 *DOE welcomes recommendations on data sources for shipments of electric motors by different product classes and long-term trends in electric motor shipments.*

9.2 Accounting Methodology

DOE hopes to develop estimates for the current stock of motors in each product class in each common motor application. Using these stock estimates, together with motor lifetime estimates, DOE proposes to determine annual shipments for the base case. DOE will also account for new motor installation, motor replacements due to failure, and motor retrofits as discussed below:

- *New Construction* – new motors that are installed each year due to equipment growth in a particular sector. DOE proposes to determine this by using the National Energy Modeling System (NEMS) growth projections for the commercial and industrial equipment sectors.

- *Replacements* – motors that have failed or that are included in equipment that fails. DOE bases this calculation on equipment sales and retirement rates.

- *Retrofits* – motors replacing existing motors during renovation and/or repair of equipment. This replacement may occur before the original motor has failed.

DOE intends to use an accounting model method to prepare shipment scenarios for the base case and the standards level cases. The model will estimate the aging and replacement of electric motors based on future motor sales growth.

Item 28 *DOE welcomes comment on the accounting methodology described above for each product class covered in this rulemaking. DOE especially invites comments regarding the stock of motors in use in different applications and motor lifetimes in each application.*

9.3 Standards Impacts on Motor Shipments

For each product class, DOE will develop a set of shipment forecasts for each set of the standards analyzed. DOE will use these standards case forecasts to evaluate the impacts of standards on motor shipments during the national impact analysis (section 10).

DOE derives standards case forecasts using the same data sets used in base case forecasts. However, because the standards case forecasts take into account the usual increase in purchase price and the usual decrease in operating costs caused by standards, forecasted shipments typically deviate from the base case. The magnitude of the difference between the standards case and base case shipment forecasts depends on the estimated purchase price increase, as well as the operating-cost savings from the standard. Because the purchase price tends to have a larger impact than operating cost on equipment purchase decisions, standards case forecasts typically show an elasticity of demand, manifested as a drop in shipments relative to the base case. DOE is also interested in cross-elasticity between motors analyzed in this rulemaking process and other motor technologies, such as DC motors.

Market-pull programs, such as customer rebate programs that encourage the purchase of more efficient motors and manufacturer tax credits that encourage the production of more efficient motors, also affect standards case forecasts. To the extent that such programs exist, DOE will consider their impact on the forecast of both standards case and base case shipments.

Item 29 *DOE welcomes comment on how any standard for electric motors might impact shipments of these motors, as well as interactions between the market for these motors and the market for motors using other technologies. DOE also invites information about market-pull programs that promote the adoption of more-efficient motors.*

10 NATIONAL IMPACT ANALYSIS

Section 8 discusses methods for estimating the LCC savings and payback period for individual customers. This section discusses DOE's assessment of the aggregate impacts of proposed efficiency standards at the national level. Impact measures that DOE will report include future NES from candidate motor standards (*i.e.*, the cumulative incremental energy savings from an electric motors efficiency standard) and the NPV of total customer LCC.

10.1 Inputs to Forecasts

DOE analyzes impacts of energy conservation standards for electric motors by projecting U.S. motor energy consumption with, and without, new energy conservation standards. These forecasts project unit energy consumption of new motors, annual equipment shipments, and the price of purchased equipment. Base case shipments forecasts are discussed in section 9, equipment retail prices are described in section 7, and unit energy consumption estimates are described in section 6.

10.2 Calculation of National Energy Savings

DOE intends to calculate national energy consumption for each year beginning with the expected compliance date of the standards. It will calculate national motor energy consumption for the base case and each standard level analyzed. DOE plans to perform this calculation through the use of a spreadsheet model that effectively multiplies annual shipment forecasts by unit energy savings, thereby accounting for the stock of equipment affected by standards.

In response to comments by stakeholders who asked for a simple, transparent model, DOE developed NES spreadsheet models for its standards rulemakings starting in 1996. NES spreadsheet models project energy savings and demonstrate how the growth in efficiency can be accounted for over time.[18] Although these spreadsheet models are specific to each product, their general framework is applicable to the entire motors market. DOE expects that the NES spreadsheet models will provide a credible, stand-alone forecast of national energy savings and NPV of energy conservation standards for electric motors.

Item 30 *DOE welcomes comment on the NES spreadsheet models it proposes to use for estimating national impacts of energy conservation standards for electric motors.*

10.3 Net Present Value of Customer Benefits

DOE calculates the national NPV of customer benefits from energy conservation standards in conjunction with the NES. To develop the national NPV, DOE must calculate annual energy expenditures and annual equipment expenditures for the standards cases. DOE calculates annual energy expenditures from annual energy consumption by incorporating forecasted energy prices, using the shipment and average energy efficiency forecasts described in section 9. DOE calculates annual equipment expenditures by multiplying the price per unit times the forecasted shipments.. The difference each year between energy bill savings and increased equipment expenditures is the net savings (if positive) or net costs (if negative). DOE will discount these annual values to the present time and sum them to provide a NPV. According to U.S. Office of Management and Budget (OMB) requirements, DOE will conduct two NPV calculations, one using a real discount rate of three percent and another using a real discount rate of seven percent (OMB, *Circular A-4: Regulatory Analysis* (2003). After considering the comments received on its preliminary analysis, DOE will make any necessary changes to the analysis and the CSLs.

11 LIFE-CYCLE COST SUBGROUP ANALYSIS

The LCC analysis described in section 8 analyzes the impacts of energy conservation standards on customers. For the subgroup analysis, DOE divides customers into subgroups, which comprise a subset of the population that is likely, for one reason or another, to be affected disproportionately by new or revised energy conservation standards (*e.g.*, small businesses or firms that use covered motors in particular applications where energy savings are likely to be small). The purpose of a subgroup analysis is to determine the extent of this disproportional impact. DOE will work with stakeholders early in the rulemaking process to identify any subgroups for this consideration. However, it will not conduct a subgroup analysis until the NOPR stage of this rulemaking.

DOE will use a number of inputs to compare potential impacts on the different customer subgroups, including: variations in regional electricity prices, variations in usage profiles, and variations in installation costs. To the extent possible, DOE may obtain estimates of the

[18] Several examples of NES spreadsheet models from previous rulemakings can be found on DOE's website at: http://www.eere.energy.gov/buildings/appliance_standards/.

variability in each input factor and consider this variability in its calculation of customer impacts. It will discuss with stakeholders the variability in each input factor and likely sources of information.

Item 31 *DOE welcomes comment on what, if any, customer subgroups are appropriate in considering standards for electric motors.*

12 MANUFACTURER IMPACT ANALYSIS

The manufacturer impact analysis assesses the potential impacts of energy conservation standards on manufacturers of electric motors. DOE intends to conduct a separate manufacturer impact analysis for each of the product classes covered under this rulemaking, i.e., general purpose electric motors (subtypes I and II), fire pump motors, and NEMA Design B general purpose electric motors. In addition to financial impacts, manufacturers may face a wide range of quantitative and qualitative effects following adoption of a standard that may require changes to motor manufacturing practices. DOE will identify these effects through confidential interviews with manufacturers and other experts.

Previously, DOE did not report any manufacturer impact analysis results prior to the NOPR phase. However, DOE changed its manufacturing impact analysis format in 2006.[19] Under this new format, DOE will collect, evaluate, and report preliminary information and data in the preliminary analysis. Such preliminary information includes the anticipated conversion capital expenditures by efficiency level and the corresponding anticipated impacts on employment. DOE will invite further input on these issues during its preliminary analysis confidential manufacturer interviews. This data collection phase is identified as the Preliminary Manufacturer Impact Analysis in Figure 2.1. In the NOPR phase, DOE will develop the Manufacturer Impact Analysis, including developing the industry cash flow analysis and conducting a thorough assessment of impacts of standards on manufacturer subgroups, direct employment, and competition.

12.1 Sources of Information for the Manufacturer Impact Analysis

Many of the analyses described earlier provide important information that DOE will use as inputs for the manufacturer impact analysis. Such information includes financial parameters developed in the market assessment (section 3), manufacturing costs and prices from the engineering analysis (section 5), retail price forecasts (section 7), and shipments forecasts (section 9). DOE will supplement this information with information gathered during confidential manufacturer interviews. The interview process plays a key role in the manufacturer impact analysis, because it provides an opportunity for directly affected parties to express their views on important issues.

[19] DOE announced changes to the manufacturer impact analysis format in a report issued to Congress on January 31, 2006 (as required by section 141 of the Energy Policy Act of 2005). This report, entitled "Energy Conservation Standards Activities," (Standards Activities) is available at: http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/congressional_report_013106.pdf.

To this end, DOE's contractor will conduct detailed confidential interviews with manufacturers pursuant to a confidentiality agreement to gain insight into the range of potential impacts from standards. During the interviews, DOE's contractor will take note of the possible impacts from standards on manufacturing costs, equipment prices, sales, direct employment, capital assets, and industry competitiveness. Both qualitative and quantitative information are valuable in terms of this analysis. DOE's contractor will schedule interviews well in advance of the actual interview to provide every opportunity for key individuals to participate.

DOE's contractor will collate and aggregate the interview results and prepare a summary of the major issues and outcomes, without manufacturer attribution. This summary will become part of the technical support document for this rulemaking.

12.2 Industry Cash Flow Analysis

The industry cash flow analysis will rely primarily on the Government Regulatory Impact Model (GRIM). DOE uses the GRIM to analyze the financial impacts of new or more stringent energy conservation standards on the industry that produces the equipment covered by the standard.

The GRIM analysis uses a number of factors—annual expected revenues, manufacturer costs such as costs of goods sold, SG&A costs, taxes, and capital expenditures (both ordinary capital expenditures and those related to standards)—to determine annual cash flows associated with a new standard, beginning from the announcement of the standard (publication of the final rule) and continuing for several years after its implementation. DOE compares the results against base case projections that involve no new standards. The financial impact of new standards is the difference between the discounted base case and standards case annual cash flows. Other performance metrics, such as return on invested capital, are also available from the GRIM.

12.3 Manufacturer Subgroup Analysis

It is possible that the use of average industry cost values will not adequately assess differential impacts among subgroups of motor manufacturers. DOE recognizes that smaller manufacturers, niche players, and manufacturers exhibiting a cost structure that differs significantly from the industry average may be impacted differently by the imposition of standards. Ideally, DOE would consider the impact on every firm individually. In highly concentrated industries, this may be possible. In industries having numerous participants, however, DOE uses the results of the market and technology assessment to group manufacturers into subgroups, as appropriate. For electric motors, DOE does not intend to assess the impacts on every manufacturer individually and, therefore, seeks feedback about potential subgroups from interested parties.

12.4 Competitive Impacts Analysis

EPCA directs DOE to consider any lessening of competition that is likely to result from an imposition of standards. (42 U.S.C. 6295(o)(2)(B)(i)(V)) It further directs the Attorney General to determine in writing the impacts, if any, of any lessening of competition. (42 U.S.C. 6295(o)(2)(B)(ii))

DOE will make a determined effort to gather firm-specific financial information and impacts, and it will then report the aggregated impact of the standard on manufacturers. The competitive impacts analysis will focus on assessing the impacts to smaller, yet significant, manufacturers. DOE will base the assessment on manufacturing cost data and on information collected from interviews with manufacturers. The manufacturer interviews will focus on gathering information that would help in assessing asymmetrical cost increases to some manufacturers, increased proportion of fixed costs potentially increasing business risks, and potential barriers to market entry (*e.g.*, proprietary technologies). DOE will provide the Attorney General a copy of the NOPR for consideration in its evaluation of the impact of standards on the lessening of competition.

12.5 Cumulative Regulatory Burden

DOE is aware that other regulations may apply to equipment covered under this rulemaking, as well as to other equipment produced by the same manufacturers of equipment covered under this rulemaking. Multiple regulations may result in a significant cumulative regulatory burden on these manufacturers. DOE will analyze and consider the impact on motor manufacturers of multiple, equipment-specific regulatory actions.

Regulations that could affect the industry impacted by this rulemaking include:

- Existing energy conservation standards and test procedures for certain 1 to 200 horsepower electric motors established in EPACT 1992 and prescribed by DOE on October 5, 1999 (64 Fed. Reg. 54114).
- Standards applicable to products that are already regulated and incorporate electric motors.
- Safety or other requirements associated with covered equipment.

Item 32 *DOE welcomes comment on key issues related to the manufacturing impact analysis.*

13 UTILITY IMPACT ANALYSIS

To estimate the effects of energy conservation standards for electric motors on the electric utility industry, DOE plans to use a variant of EIA's NEMS, called NEMS-BT (BT refers to DOE's Building Technologies Program). NEMS is a large, multi-sectoral partial equilibrium model of the U.S. energy sector, used primarily for the purpose of preparing EIA's *AEO*. NEMS-BT produces a widely recognized reference case forecast for the United States through 2030 and is available in the public domain.

The utility impact analysis is a comparison between the NEMS-BT model results for the base case and standards cases. Outputs of the utility impact analysis usually parallel results that appear in the latest *AEO*, with some additions. Typical outputs include forecasts of electricity generation, sales, price, and avoided capacity. DOE plans to model the energy savings impacts

from energy conservation standards for electric motors using NEMS-BT to generate forecasts that deviate from the *AEO* reference case.[20]

Item 33 *DOE welcomes input from stakeholders on its proposed use of NEMS-BT to conduct the utility impact analysis.*

14 EMPLOYMENT IMPACT ANALYSIS

The Process Rule includes employment impacts among the factors for DOE to consider in selecting a proposed energy conservation standard; it also provides guidance for consideration of the impact of TSLs on both direct and indirect employment. The Process Rule includes a general presumption against any TSL that would directly cause plant closures, significant loss of domestic employment, or significant losses of capital investment unless specifically identified, expected benefits of the standard would outweigh such adverse effects.[21]

DOE estimates the impacts of standards on employment for equipment manufacturers, relevant service industries, energy suppliers, and the economy in general. Its analysis covers both direct and indirect employment impacts. Direct employment impacts would result if standards led to a change in the number of employees at manufacturing plants and related supply and service firms. Direct impact estimates are covered in the manufacturer impact analysis (section 12).

Indirect employment impacts are impacts on the national economy other than in the manufacturing sector being regulated. Indirect impacts may result from both expenditures shifting among goods (the substitution effect) and changes in income that lead to a change in overall expenditure levels (the income effect). DOE defines indirect employment impacts from standards as net jobs eliminated or created in the general economy as a result of increased spending driven by the increased equipment prices and reduced spending on energy. DOE expects new standards for electric motors to increase the total installed cost of equipment (which includes manufacturer selling price, sales taxes, distribution chain markups, and installation cost). DOE also expects the new standards to decrease energy consumption, and thus energy expenditures. Over time, DOE expects that the increased total installed cost will be recouped through energy savings. The savings in energy expenditures may be spent on new commercial investment and other items.

The Department intends to base its analysis on an input/output model of the U.S. economy that estimates the effects of standards on major sectors of the economy related to buildings and the net impact of standards on jobs. The Pacific Northwest National Laboratory developed the model, called ImSET (Impact of Sector Energy Technologies), as a successor to ImBuild, a special-purpose version of the IMPLAN national input/output model. ImSET estimates the employment and income effects of energy-efficient technologies in buildings,

[20] Several NEMS-BT models from previous rulemakings can be found on the DOE's website at http://www.eere.energy.gov/buildings/appliance_standards/.

[21] See 10 CFR Part 430, Subpart C, Appendix A, 4(d)(7)(ii), (vi) and 5(e)(3)(i)(B).

power, industry, and transportation. Compared to simple economic multiplier approaches, ImSET allows for more complete and automated analysis of the economic impacts of energy-efficiency investments.

In an input/output model such as ImSET, the level of employment in an economy is determined by the relationship of different sectors of the economy and the spending flows among them. Different sectors have different levels of labor intensity, so changes in the level of spending (*e.g.*, due to the effects of an energy conservation standard) in one sector of the economy will affect spending flows in other sectors. This paradigm affects the overall level of employment.

ImSET uses a 188-sector model of the national economy to predict the economic effects of energy efficient technologies. ImSET collects estimates of initial investments, energy savings, and economic activity associated with spending the savings resulting from standards (*e.g.*, changes in personal consumption, business investment and spending, and government spending). The model provides overall estimates of the change in national output for each input-output sector by applying estimates of employment and wage income per dollar of economic output for each sector and calculating impacts on national employment and wage income.

Energy efficiency technology primarily affects the U.S. economy along three spending pathways. First, general investment funds are diverted to sectors that manufacture, install, and maintain energy efficient appliances. The increased cost of equipment increases employment in the equipment manufacturing sectors and decreases employment in other economic sectors. Second, commercial and industrial firm and residential spending are redirected from utilities toward firms that supply production inputs. Third, electric utility sector investment funds are released for use in other sectors of the economy. When customers use less energy, electric utilities experience relative reductions in demand, which leads to reductions in utility sector investment and employment.

Item 34 *DOE welcomes feedback on its proposed approach to assessing national employment impacts, both direct and indirect.*

15 ENVIRONMENTAL ASSESSMENT

To comply with the National Environmental Policy Act and the requirements of 42 U.S.C. 6295(o)(2)(B)(i)(VI) and 6316(a), DOE intends to prepare an environmental assessment of the impacts of amended energy conservation standards for electric motors on the human environment. The primary environmental effects of these standards would be reduced power plant emissions resulting from reduced consumption of electricity. DOE will assess these environmental effects by using NEMS-BT to provide key inputs to its analysis. The portion of the environmental assessment that will be produced by NEMS-BT considers carbon dioxide (CO_2), nitrogen oxides (NO_X), and mercury (Hg). The environmental assessment also considers impacts on SO_2 emissions and discuss particulate matter (PM) emissions. After a brief discussion of general methodology, this section will address each of the relevant emissions. This section then explains how DOE plans to monetize the benefits associated with emissions reductions.

15.1 Carbon Dioxide

In the absence of any Federal emissions control regulation of power plant emissions of CO_2, a DOE standard is likely to result in reductions of these emissions. The CO_2 emission reductions likely to result from a standard will be estimated using NEMS-BT and national energy savings estimates drawn from the NIA spreadsheet model. The net benefit of the standard is the difference between emissions estimated by NEMS-BT at each standard level considered and the *AEO* Reference Case. NEMS-BT tracks CO_2 emissions using a detailed module that provides results with broad coverage of all sectors and inclusion of interactive effects.

15.2 Sulfur Dioxide

DOE has preliminarily determined that SO_2 emissions from affected Electric Generating Units (EGUs) are subject to nationwide and regional emissions cap and trading programs that create uncertainty about the standards' impact on SO_2 emissions. Title IV of the Clean Air Act sets an annual emissions cap on SO_2 for all affected EGUs. SO_2 emissions from 28 eastern States and the District of Columbia (D.C.) are also limited under the Clean Air Interstate Rule (CAIR, published in the Federal Register on May 12, 2005, 70 Fed. Reg. 25162, which creates an allowance-based trading program that will gradually replace the Title IV program in those States and DC. (The recent legal history surrounding CAIR is discussed below.) The attainment of the emissions caps is flexible among EGUs and is enforced through the use of emissions allowances and tradable permits under both programs. Under existing EPA regulations, any excess SO_2 emission allowances resulting from the lower electricity demand caused by the imposition of an efficiency standard could be used to permit offsetting increases in SO_2 emissions by any regulated EGU. However, if the standard resulted in a permanent increase in the quantity of unused emission allowances, there would be an overall reduction in SO_2 emissions from the standards. While there remains some uncertainty about the ultimate effects of efficiency standards on SO_2 emissions covered by the existing cap and trade system, the NEMS-BT modeling system that DOE uses to forecast emissions reductions currently indicates that no physical reductions in power sector emissions would occur for SO_2.

15.3 Nitrogen Oxides

NEMS-BT also has an algorithm for estimating NO_X emissions from power generation. The impact of these emissions, however, will be affected by the CAIR, which the Environmental Protection Agency (EPA) issued on May 12, 2005. CAIR will permanently cap emissions of NO_X in 28 eastern states and the District of Columbia. 70 FR 25162 (May 12, 2005).

Much like SO_2 emissions, a cap on NO_X emissions means that the amended electric motors standards may have little or no physical effect on these emissions in the 28 eastern States and the DC covered by CAIR. Although CAIR has been remanded to the EPA by the U.S. Court of Appeals for the District of Columbia (DC Circuit), it will remain in effect until it is replaced by a rule consistent with the Court's July 11, 2008, opinion in *North Carolina v. EPA*, 531 F.3d 896 (D.C. Cir. 2008); see also *North Carolina v. EPA*, 550 F.3d 1176 (D.C. Cir. 2008). Because all States covered by CAIR opted to reduce NO_X emissions through participation in cap-and-trade programs for electric generating units, emissions from these sources are capped across the CAIR region.

DOE plans to use NEMS-BT to estimate the emissions reductions from possible standards in the 22 States where emissions are not capped.

15.4 Mercury

Similar to emissions of SO_2 and NO_X, future emissions of Hg would have been subject to emissions caps. In May 2005, EPA issued the Clean Air Mercury Rule (CAMR). 70 Fed. Reg. 28606 (May 18, 2005). CAMR would have permanently capped emissions of mercury for new and existing coal-fired power plants in all States by 2010. However, on February 8, 2008, the DC Circuit issued its decision in *New Jersey v. Environmental Protection Agency*, in which the DC Circuit, among other actions, vacated the CAMR. 517 F.3d 574 (D.C. Cir. 2008). EPA has decided to develop emissions standards for power plants under the Clean Air Act (Section 112), consistent with the DC Circuit's opinion on the CAMR. See http://www.epa.gov/air/mercuryrule/pdfs/certpetition_withdrawal.pdf. Pending EPA's forthcoming revisions to the rule, DOE is excluding the CAMR from its Environmental Analysis. In the absence of CAMR, a DOE standard would likely reduce Hg emissions and DOE plans to use NEMS-BT to estimate these emission reductions. However, DOE continues to review the impact of rules that reduce energy consumption on Hg emissions, and may revise its assessment of Hg emission reductions in future rulemakings.

15.5 Particulate Matter

DOE acknowledges that particulate matter (PM) exposure can impact human health. Power plant emissions can have either direct or indirect impacts on PM. A portion of the pollutants emitted by a power plant are in the form of particulates as they leave the smoke stack. These are direct, or primary, PM emissions. However, the great majority of PM emissions associated with power plants are in the form of secondary sulfates, which are produced at a significant distance from power plants by complex atmospheric chemical reactions that often involve the gaseous (non-particulate) emissions of power plants, mainly SO_2 and NOx. The quantity of the secondary sulfates produced is determined by a very complex set of factors including the atmospheric quantities of SO_2 and NOx, and other atmospheric constituents and conditions. Because these highly complex chemical reactions produce PM comprised of different constituents from different sources, EPA does not distinguish direct PM emissions from power plants from the secondary sulfate particulates in its ambient air quality requirements, PM monitoring of ambient air quality, or PM emissions inventories. For these reasons, it is not currently possible to determine how the amended standard impacts either direct or indirect PM emissions. Therefore, DOE is not planning to assess the impact of these standards on PM emissions. Further, as described previously, it is uncertain whether efficiency standards will result in a net decrease in power plant emissions of SO_2 and NOx, since those pollutants are now largely regulated by cap and trade system.

Item 35 *DOE seeks input on its plans to use NEMS-BT to conduct the environmental assessment for the products covered by this rulemaking.*

16 MONETIZATION OF EMISSIONS REDUCTIONS

For those emissions for which real national emission reductions are anticipated (CO_2, Hg, and NO_X for 22 States), only ranges of estimated economic values based on environmental damage studies of varying quality and applicability are available. Therefore, DOE intends to report estimates of monetary benefits derived using these values and consider these benefits in weighing the costs and benefits of each of the standard levels considered.

In order to estimate the monetary value of benefits resulting from reduced emissions of CO_2 emissions, DOE intends to use in its analysis the most current Social Cost of Carbon (SCC) values developed and/or agreed to by interagency reviews. The SCC is intended to be a monetary measure of the incremental damage resulting from greenhouse gas (GHG) emissions, including, but not limited to, net agricultural productivity loss, human health effects, property damage from sea level rise, and changes in ecosystem services. Any effort to quantify and to monetize the harms associated with climate change will raise serious questions of science, economics, and ethics. But with full regard for the limits of both quantification and monetization, the SCC can be used to provide estimates of the social benefits of reductions in GHG emissions.

At the time of this notice, the most recent interagency estimates of the potential global benefits resulting from reduced CO_2 emissions in 2010 were $4.7, $21.4, $35.1, and $64.9 per metric ton in 2007 dollars. These values are then adjusted to 2009$ using the standard gross domestic product (GDP) deflator value for 2008 and 2009. For emissions (or emission reductions) that occur in later years, these values grow in real terms over time. Additionally, the interagency group determined that a range of values from 7 percent to 23 percent should be used to adjust the global SCC to calculate domestic effects, although DOE will give preference to consideration of the global benefits of reducing CO_2 emissions. To calculate a present value of the stream of monetary values, DOE will discount the values in each of the four cases using the discount rates that had been used to obtain the SCC values in each case.

DOE recognizes that scientific and economic knowledge continues to evolve rapidly as to the contribution of CO_2 and other GHG to changes in the future global climate and the potential resulting damages to the world economy. Thus, these values are subject to change.

DOE also intends to estimate the potential monetary benefit of reduced NO_X emissions resulting from the standard levels it considers. For NO_X emissions, available estimates suggest a very wide range of monetary values for NO_X emissions, ranging from $370 per ton to $3,800 per ton of NO_X from stationary sources, measured in 2001$ (equivalent to a range of $447 to $4,591 per ton in 2009$). Refer to the OMB, Office of Information and Regulatory Affairs (OIRA), "2006 Report to Congress on the Costs and Benefits of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities" for additional information. In accordance with OMB guidance, DOE will conduct two calculations of the monetary benefits derived using each of the economic values used for NO_X, one using a real discount rate of 3 percent and another using a real discount rate of 7 percent.

DOE does not plan to monetize estimates of Hg in this rulemaking. DOE is aware of multiple agency efforts to determine the appropriate range of values used in evaluating the potential economic benefits of reduced Hg emissions. DOE has decided to await further guidance

regarding consistent valuation and reporting of Hg emissions before it once again monetizes Hg in its rulemakings.

Item 36 *DOE requests comments on the approach it plans to use for estimating monetary values associated with emissions reductions, or any widely-accepted values that could be used in DOE's analyses.*

17 REGULATORY IMPACT ANALYSIS

Under the Process Rule, DOE is committed to exploring non-regulatory alternatives to mandatory standards. (See the Process Rule, 10 CFR Part 430, Subpart C, Appendix A, section 12.) In the NOPR stage of this rulemaking, DOE will prepare a regulatory impact analysis as required by Executive Order 12866.[22] The regulatory impact analysis will address the potential for non-regulatory approaches to supplant or augment energy conservation standards to improve the efficiency of electric motors in the market.

DOE recognizes that voluntary or other non-regulatory efforts by manufacturers, utilities, and other interested parties can result in substantial efficiency improvements. DOE intends to consider the likely effects of non-regulatory initiatives on motor energy use, customer utility, and life-cycle costs. DOE will take into account the actual impacts of any existing initiatives to date, but also will consider historical information that may reasonably estimate the impacts that any such initiative may have in the future. It will use the NES spreadsheet model (as discussed in section 10.2) to calculate the NES and NPV for the non-regulatory alternatives.

Item 37 *DOE invites comments on the ability of voluntary initiatives or other non-regulatory efforts by manufacturers to achieve significant energy savings and reasonable costs.*

[22] 58 Fed. Reg. 51735 (Oct. 4, 1993).

APPENDIX A SUMMARY OF ITEMS FOR STAKEHOLDER COMMENT

Item 1 DOE welcomes comment on any additional test procedures that should be considered or comments about the test procedures listed. 7

Item 2 DOE welcomes interested party comment on the proposed product class-setting criteria outlined for this rulemaking. In particular, DOE is interested in feedback regarding the continued aggregation of NEMA Design A and Design B motors, the disaggregation of NEMA Design C motors from Design A and B motors, and the disaggregation of U-Frame motors, T-Frame motors, and vertical mount motors. Finally, DOE is also interested in its proposal to not use close-coupled pump design as a product class setting criterion. 18

Item 3 DOE requests comment on the technology options for reducing I^2R losses. In particular, DOE understands that the 0.0125 small electric motor tolerance may be different for electric motors and seeks comment on what an appropriate air gap may be for electric motors covered by this rulemaking..... 20

Item 4 DOE requests comment on the technology options for reducing core losses. In particular, DOE seeks comment on the most appropriate steels, both "conventional" and "exotic," that it should consider in its analysis. 22

Item 5 DOE seeks any information regarding recent developments of plastic iron powder technology and comments on whether DOE should consider it in its analysis for electric motors. 23

Item 6 DOE requests comment on the technology options for reducing friction and windage losses. 23

Item 7 DOE welcomes comment on the technology options identified in this section. DOE welcomes comment on whether there are other technology options that it should also consider. 24

Item 8 DOE welcomes comments on how the above four screening criteria might apply to the technology options discussed in the market and technology assessment. 25

Item 9 DOE welcomes input from interested parties on a software package that would be appropriate for use in developing the max-tech models for each electric motor analyzed..... 26

Item 10 DOE welcomes comment on whether it has identified the representative product classes and representative units appropriately. DOE also welcomes comment on the appropriate horsepower ratings, pole configurations, and motor enclosures to analyze for each of the proposed motor designs. 27

Item 11 For each product class, DOE welcomes interested party comment on methods and approaches employed to improve the efficiency of the motors, including the max-tech model. Detailed information on the motor performance and the incremental manufacturing costs (e.g., material costs, labor costs, overhead costs (excluding depreciation), building conversion capital expenditures, tooling/equipment conversion capital expenditures associated with more efficient designs, research and development (R&D) expenses, and marketing expenses) would be useful. 29

Item 12 DOE welcomes comment on the markup approach proposed for developing estimates of manufacturer selling prices. 29

Item 13 DOE welcomes comment on the above-described approach to determining the relationship between manufacturer selling price and motor efficiency. 29

Item 14 DOE welcomes comment on whether there are proprietary designs it should consider for any of the motor designs under consideration in this rulemaking and, if so, how DOE should acquire the cost data necessary for evaluating these designs. 29

Item 15 DOE welcomes comment from interested parties on the best methodology for scaling from the representative product classes to the remaining product classes, including the proposed methodology of using a power law function and an industry-accepted equation for motor losses to model the efficiency relationships established by EISA 2007. 32

Item 16 DOE also welcomes comment from interested parties on the best approach for scaling from open motors to enclosed motors (or vice versa). 32

Item 17 DOE welcomes comment on whether there are outside regulatory changes that DOE should consider in its engineering analysis of electric motors. 32

Item 18 DOE seeks to identify and obtain detailed data on the typical applications and end-use profiles for the motors considered in this rulemaking. If the range of energy use determined for each product class is large enough, DOE will conduct a sensitivity analysis to determine how high and low estimates of energy use might impact the economic feasibility of any amended energy conservation standards. DOE welcomes recommendations on sources of data that would provide end-use operating profiles for each of the product classes covered under this rulemaking. 33

Item 19 DOE welcomes comment on whether the end-use operating profiles are different for each of the product classes covered under this rulemaking, as well as how the profiles may be different. 33

Item 20 DOE welcomes comments regarding motor repair practices and their impact on motor energy use. 33

Item 21 DOE welcomes comment on other end-use issues that could impact the energy use analysis. 33

Item 22 DOE welcomes comment on the distribution chain for electric motors, the key stakeholders in those distribution chains, the typical markups applied by those stakeholders, and the overall markup from manufacturer selling price to consumer retail price. 34

Item 23 DOE welcomes input on the proposed methodology for estimating current and future electricity prices. 35

Item 24 DOE welcomes input on the proposed approaches for estimating discount rates for customers of motors covered under this rulemaking. 36

Item 25 DOE welcomes comment on whether and how to develop maintenance, repair, and installation costs for electric motors. Specifically, DOE invites comment on how efficiency requirements may affect the ability of motor designs to fit in constrained spaces and configurations. DOE also invites comment on changes in repair practices that may accompany more efficient motors. 36

Item 26 DOE welcomes comment on appropriate motor lifetimes for the product classes covered in this rulemaking, as well as data regarding correlation between motor end-use patterns and motor lifetime. 37

Item 27 DOE welcomes recommendations on data sources for shipments of electric motors by different product classes and long-term trends in electric motor shipments. 38

Item 28 DOE welcomes comment on the accounting methodology described above for each product class covered in this rulemaking. DOE especially invites comments regarding the stock of motors in use in different applications and motor lifetimes in each application. 38

Item 29 DOE welcomes comment on how any standard for electric motors might impact shipments of these motors, as well as interactions between the market for these motors and the market for motors using other technologies. DOE also invites information about market-pull programs that promote the adoption of more-efficient motors. 39

Item 30 DOE welcomes comment on the NES spreadsheet models it proposes to use for estimating national impacts of energy conservation standards for electric motors. 40

Item 31 DOE welcomes comment on what, if any, customer subgroups are appropriate in considering standards for electric motors. 41

Item 32 DOE welcomes comment on key issues related to the manufacturing impact analysis. 43

Item 33 DOE welcomes input from stakeholders on its proposed use of NEMS-BT to conduct the utility impact analysis. 44

Item 34 DOE welcomes feedback on its proposed approach to assessing national employment impacts, both direct and indirect. 45

Item 35 DOE seeks input on its plans to use NEMS-BT to conduct the environmental assessment for the products covered by this rulemaking. 47

Item 36 DOE requests comments on the approach it plans to use for estimating monetary values associated with emissions reductions, or any widely-accepted values that could be used in DOE's analyses. 49

Item 37 DOE invites comments on the ability of voluntary initiatives or other non-regulatory efforts by manufacturers to achieve significant energy savings and reasonable costs. 49