Consortium for Energy Efficiency
Premium-Efficiency Motors Initiative[1]

NOTICE OF JUNE 15, 2007

This initiative was written in 1996, prior to the introduction of NEMA Premium motors into the market. It covered only those motors included under the EPAct 1992 legislation.

CEE is currently in the process of expanding and revising this document in light of current market conditions and the existence of NEMA Premium® brand motors. This revision entails 1) assessing opportunities to add additional equipment and process recommendations (e.g. other motor categories and motor management) and 2) updating the initiative accordingly.

As a first step, CEE has assessed and added large (250-500 hp), low-voltage, general-purpose motors to the Initiative by including Appendix 2: *Guidance Specification for Large, Low-Voltage, General-Purpose Motors*. Participation requirements for this portion of the initiative are detailed in the appendix and are in accordance with the participation requirements of the full initiative.

Additional categories of motors are scheduled for review in 2007. Once the scope of products and the recommendations for each have been clarified, the body of this initiative will be fully revised.

INTRODUCTION

Electric motor systems account for more than half of all electricity consumed in the United States and almost 70 percent of manufacturing sector electricity consumption. Motor electricity consumption can approach 90 percent of some industries' (e.g. pulp and paper, textiles) total electricity bill. The Consortium for Energy Efficiency formed its Motor Systems Committee to explore how it could help improve the efficiency of motor driven systems. The committee identified four areas in which CEE initiatives might be developed: motor repair, performance optimization, original equipment manufacturers (OEMs), and motor efficiency levels. This initiative, which concerns the efficiency of the motor itself, is the first of several which the committee anticipates launching to improve overall motor system efficiency.[2]

This initiative is timed to be useful for both utilities with ongoing motors programs as well as those that might be interested in initiating a new motors effort. Federal regulations will raise the minimum efficiency for motors manufactured after October 1997 and many utilities will want to revise their ongoing motors programs to reflect these changes. In addition, many utilities are considering new motors programs as a way to deliver value to important customers in an emerging competitive environment.

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[1] This project has been funded in part by grant support from the U.S. Department of Energy. The Consortium for Energy Efficiency is funded by members' dues as well as by grants from the U.S. Department of Energy and the U.S. Environmental Protection Agency.
[2] The CEE Motor Systems Committee anticipates launching initiatives concerning performance optimization and repair practice later in 1996 or early in 1997. The committee has yet to determine an approach for OEMs. Improving the efficiency of motors offers large potential savings. However, the total savings potential for each of the other three areas being investigated for a potential CEE initiative is much larger.

Why is motor efficiency important?

In general, motors turn electrical energy in to mechanical energy very efficiently. Nevertheless, for most motor types, a range of efficiencies is available. Because even small efficiency improvements often make economic sense for equipment operated thousands of hours per year, the overall opportunity for energy savings from more efficient motors remains large.[3]
Utility programs targeted at industrial and commercial motor users can provide substantial value to key customers. By enabling a customer to cost-effectively reduce its energy bill without compromising motor performance, a utility provides a valuable service. Typically, the annual operating cost of a motor far outstrips the initial purchase price. For instance a typical 75 horsepower (hp) motor running at full load for 8,000 hours per year would consume about $24,000 worth of electricity at $0.05 per kWh. A typical purchase price for such a motor is about $4,000.[4] A utility that helps a customer address the operating costs of a motor helps that customer with, by far, the largest expense associated with the motor. As the utility industry enters a highly competitive, market-driven environment, such services will help utilities build stronger relationships with their customers.

Why a national motors initiative?

Motors programs are already among the most common and effective programs offered by utilities to their commercial and industrial customers. With the impending implementation of new minimum efficiency standards for electric motors as required by the Energy Policy Act of 1992 (EPAct), many ongoing utility programs will need to raise their qualifying levels. In addition, many utilities which have had relatively small-scale programs or no motors program at all are now considering developing or expanding motors programs in order to increase the value they offer to key customers. These developments create the opportunity for a national initiative that will encourage the market for premium-efficiency motors.

This initiative is intended to maximize the market impact of all motors programs and to minimize confusion in the marketplace. By creating a common definition of “premium-efficiency” which many utilities can adopt, the initiative will help set clear targets for manufacturers. Even the largest utility represents only a small fraction of the motor manufacturers’ market. However, if many utilities include common product specifications as part of their motors programs, manufacturers will be given a clear indication of the value of offering a wide selection of premium-efficiency motors.

In addition, many end-users have concerns regarding premium-efficiency motor durability, full-load speed, starting torque as well as the reliability of savings estimates. These concerns remain a barrier to more widespread adoption of premium-efficiency motors due to a lack of reliable information to address them. A critical component of this initiative brings together information that will help utilities address these issues with their customers. Furthermore, the initiative provides guidelines that help a utility determine when a premium-efficiency motor makes sense for a customer.

What are the benefits of participating?

[3] The following indicates the order of magnitude of savings that this initiative could eventually help yield: Industrial motors accounted for 574 TWh in 1991. Energy efficient motors tend to be 1% to 7% more efficient than standard efficiency motors. Motors meeting the levels designated in the program (CEE premium efficiency motors) are .8% to 4% more efficient than energy efficient motors. Therefore, a conservative assumption would be that programs involved in this initiative will encourage motors that are on average 2% more efficient than the end-user would otherwise purchase. Assuming that enough program reach is attained within the next few years to achieve an additional 1% stock penetration of motors 2% more efficient than the end-user would otherwise have acquired, the total annual savings yielded by the initiative would be about 115 GWh.
[4] Electrical Apparatus Service Association (EASA). *A Guide to AC Motor Repair* draft January 1996.

The initiative is designed to offer value to utilities that have yet to launch a motors program as well as those for which motors programs have been an important part of their marketing or energy efficiency activities. Participation in the initiative provides utilities a number of benefits:

- *Save utility resources:* CEE provides product specifications and market research that reduce the need for a utility to dedicate resources to program planning and product research. Motors experts involved in the CEE committee have shared their expertise by helping to develop appropriate specifications for determining qualifying products and by developing educational materials that address concerns regarding premium-efficiency motors.

- *Maximize customer savings:* Several utilities already plan to adopt the initiative's product specifications as the basis for their motors programs. Widespread utility adoption of these specifications will encourage increased availability of premium-efficiency motors and greater competition among manufacturers. Increased demand should encourage distributors to stock more premium-efficiency motors, making it easier for utility customers to acquire a premium-efficiency motor on short notice. Competition should lead to lower prices for premium-efficiency motors, enabling utilities to provide even greater value to their customers.

- *Gain recognition:* Participants in this initiative will be contributing to a national effort that contributes to a cleaner environment and stronger economy. As this effort increases the market share for premium-efficiency motors, it cuts emissions associated with power production. In addition, premium-efficiency motors help cut the productions costs of American industry, increasing its competitiveness. CEE will undertake an ongoing public relations effort that communicates the participants of the initiative and its accomplishments.

Furthermore, CEE will work to facilitate communications between utilities and manufacturers. CEE will compile information about participating utilities' programs on an ongoing basis. This information will be presented to manufacturers in order to encourage wider availability of qualifying motors. In addition, CEE will work with manufacturer trade associations (e.g. the National Electrical Manufacturers Association, NEMA), individual manufacturers, the Energy Efficient Procurement Collaborative, the U.S. Department of Energy's Motor Challenge Program, participating utilities, and other potential partners to identify information about equipment meeting the CEE eligibility thresholds that will be made available to participating utilities.

CEE will not (I) convey any information from or about a manufacturer to another manufacturer, or (2) communicate any non-public information from or about any utility or manufacturer.

How does a utility participate?

A utility participates in the CEE motors initiative simply by including one or more of the initiative's specifications in its motors program. All motors programs, including educational/promotional, technical assistance, and incentive programs, are eligible for inclusion in the initiative. The CEE specifications are a set of efficiency levels above those specified in EPAct. For the purposes of this initiative, motors meeting these specifications are referred to as "NEMA Premium-efficiency motors."

A critical component of the specifications are educational materials that assist customers in making prudent motor selections. There is no cost to participate in the initiative. Utilities wishing to participate in the initiative need not join CEE, although they are encouraged to do so.

Each utility wishing to participate in the initiative should inform CEE of its intent to adopt the CEE equipment and/or appropriate application components in whole or in part. A simple letter of intent, such as the sample attached, will provide this information. Individual utilities may modify this letter to suit their purposes; however, care should be taken to include all the requested information when modifying this letter.

Of course, utilities are free to include other specifications as well since the CEE program is not exclusive.

SCOPE

This program recognizes and supports the NEMA Premium definition of premium-efficiency motors for motors common to both specifications. Efficiency values are aligned with the nominal efficiencies in NEMA's MG 1-2006, table 12-12.

The NEMA Premium motors supported by this initiative are: Design A and B, three phase, integral horsepower, general purpose, open drip proof (ODP) and totally enclosed fan cooled (TEFC) motors with six poles (1200 rpm), four poles (1800 rpm) and two poles (3600 rpm), from 1-500 hp.

While both large (250-500 hp) and small motors (1-200 hp) are included under this initiative, program recommendations for these two size categories are different. Specifically,

- motors from 1-200 hp and covered under the *CEE Premium Motor Efficiency Motors Initiative – Efficiency Specifications Table © 2003*; and
- motors from 250-500 hp are covered under the *Guidance Specification for Large, Low-Voltage, General-Purpose Motors © 2007*.

Utilities and other organizations are encouraged to adopt these levels and the accompanying guidance and educational materials for all their motors programs.

DEFINITIONS

There has been significant confusion in the motors marketplace over the meaning of "high efficiency," "energy-efficient," and "premium-efficiency." The National Electrical Manufacturers Association (NEMA), the motor manufacturers' trade association, established a definition of "energy-efficient" motors in their standard MG-1, table 12-10. The efficiency levels established in table 12-10 are identical to the EPAct minimum standards which become effective as of October 1997. "Energy-efficient," therefore, also applies to motors meeting EPAct minimum standards.

No accepted common definition exists for the other terms. For the purposes of this initiative, motors meeting or exceeding the specifications described in Table 1 will be referred to as "CEE premium-efficiency" motors.

PROGRAM APPROACH

This program is comprised of two components: a table of nominal full-load efficiencies higher than NEMA 12-10 ("Equipment Efficiency Component") and an informational document describing both appropriate and inappropriate applications of the efficiency table and the motors meeting the efficiency requirements ("Appropriate Applications Component").

Equipment Efficiency Component

CEE, in cooperation with utilities, motor manufacturers, trade associations, and motor experts, developed a set of efficiency levels that are significantly higher than those specified in EPAct, but for which product is reasonably available from major motor manufacturers. These levels (CEE premium efficiency) are presented in Table I, along with the EPAct levels.

CEE undertook a review of commercially available equipment using the most recent Washington State Energy Office (WSEO) Motor Master database. The first procedure involved setting levels at which four major manufacturers offered general market product (e.g., special applications such as C-face or unusual voltage motors were excluded). These levels were reviewed to ensure that they were significantly different from the EPAct levels (i.e., at least two NEMA steps[5] above EPAct levels), and, if not, were raised to that level. The levels were then reviewed by several utilities currently offering motor efficiency programs in New England, the Midwest, the Northwest, and California, and by motor manufacturers representing NEMA. The utilities reviewed the levels to ensure that product in all categories was available from distributors in the various regions. As a result of this review, approximately ten levels were lowered one NEMA step.

Utility Participation

As described above, utilities participate in the CEE motors initiative by using the initiative's product specifications in their motors programs. Should a utility not wish to adopt these levels immediately, CEE will recognize as program participants those utilities using efficiencies at the EPAct levels (Tier 0) until July 1997, if they agree to raise qualifying levels to the CEE levels (Tier 1) at that time. Prior to July 1997, utilities using two levels, Tiers 0 and 1, will be recognized as initiative participants.

Implementation

Possible strategies for implementing this program include:

- the use of the levels in developing motor selection recommendations for educational campaigns;
- use of program levels as a purchasing specification;
- customer rebates or financing for purchase of qualifying motors;
- distributor rebates for purchase or stocking of qualifying motors; and
- selection of qualifying motors as a condition for receiving a customized incentive.

CEE does not suggest or encourage any particular utility program strategy or type.

While participating utilities are encouraged to promote all motors covered under this initiative, they may choose to only recognize some categories. For example, for simplicity's sake, a utility may choose to only include 1800 rpm TEFC motors in its program since such motors represent a large portion of motors sold.

Current Availability of CEE Premium-Efficiency Motors

CEE, in setting its levels, ensured that product was available from several manufacturers in all size categories. With the approaching October 1997 implementation of the EPAct minimum efficiency levels, manufacturers' product offerings are changing rapidly. Utilities participating in this program should be aware that a significant volume of new qualifying product will become available over the next few years. For that reason, CEE does not recommend using a fixed list of qualifying product.

[5] A step is the interval between any two successive values in the NEMA document MG-1, section 12.58.2 table 12-8. Motors are assigned nameplate efficiencies listed in this table. A NEMA band is the range of nominal full load efficiencies around a given listed efficiency level.

Eligibility of Equipment

Determination of the efficiency level met by each available motor is a daunting task. Each manufacturer is likely to have several thousand motors that fall within the scope of this program. Under the authority of EPAct, the U.S. Department of Energy (DOE) is developing a process for certifying motor efficiency. CEE proposes to adopt the EPAct process for determining which motors meet the initiative specifications. Prior to implementation of this certification process, however, CEE recommends that nameplate data supplied by manufacturers be used to qualify product for any individual utility program.[6]

Once completed, CEE proposes to adopt the DOE process for establishing compliance with EPAct for certifying which motors meet the program levels. See the appendix for a description of the DOE process.

Efficiency Levels Revision Process

The electric motor marketplace is changing in response to EPAct. Manufacturers have already begun to introduce new, higher efficiency models. While the available efficiencies for the most commonly used motors are already quite high, some smaller market share motors have not as yet achieved similar efficiencies. Given the degree of change in the market, the efficiency levels specified under this program should be reevaluated after EPAct has gone into effect.

Beginning in 1998, and every two years thereafter, the CEE motors committee, in cooperation with all stakeholders, will consider revisions to the initiative's motor efficiency levels in order to reflect any changes in the motor market. Any revised levels will be developed using the same guidelines used to develop the original (1996) levels. CEE will circulate proposed revised levels to motor manufacturers and industry experts for comment before adoption.

APPROPRIATE APPLICATION COMPONENT

As noted, there is significant confusion among users as to the characteristics of premium-efficiency motors, and how and when to best apply them. The table discussed in the previous section is intended to provide a common definition of premium-efficiency motors. If misapplied, premium-efficiency motors may achieve no energy savings and may result in diminished performance and reduced motor life. In order to ensure customer satisfaction, entities promoting premium-efficiency motors should inform customers as to both the appropriate and inappropriate application of premium-efficiency motors.

{The Motors Committee intends to work with NEMA and motor manufacturers to develop an educational document for use as part of any program that makes use of the efficiency levels in this initiative. This document will be made available to participating utilities in preprinted, camera-ready and electronic forms for use in their educational and marketing efforts.]

MARKETING

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[6] In addition to information from manufacturers, one source of motor nameplate information is the Motor Master database maintained by WSEO and available from DOE's Motor Challenge Information Clearinghouse, 1-800-862-2086. Another source is the Energy Efficient Procurement Collaborative which publishes product listings for several types of equipment including motors. This listing indicates which motors meet the specifications listed in the CEE initiative. The Collaborative can be reached at (518) 465-6251.

This initiative's impact depends upon widespread utility participation. To that end, CEE will develop focused marketing campaigns targeted at recruiting as many utility participants as possible. CEE's goal is to have utilities servicing a substantial percentage of North American customers participating in this effort beginning in 1997. Members of the CEE motors committee will participate in this marketing effort.

TECHNICAL BACKGROUND

The Motor Market

Historically, a range of efficiencies has been available from most motor manufacturers. As interest in energy efficiency grew in the late 1970s, a new, energy-efficient class of motors was introduced by many manufacturers. The design and materials choices that a motor manufacturer makes determine the efficiency of a given electric motor. This efficiency represents a tradeoff with the cost and operating characteristics such as torque. Typically, energy-efficient motors cost between 15 and 30 percent more than standard efficiency motors.

This initiative concerns integral horsepower AC polyphase induction motors, the greatest fraction of industrial and commercial motor horsepower. Annual sales are almost $1 billion. There are twelve major motor manufacturers represented in this market. Forty percent of new motors reach end-users as discrete components. Most of these motors are sold by distributors who may be large electrical supply houses, motor repair shops, or specialty distributors. The remaining 60 percent are sold to original equipment manufacturers (OEMs) for use as components in motor-driven equipment.[7]

Though motors are one of the largest consumers of electricity, knowledge of their installed stock, performance, and usage is limited. It is estimated that currently, energy-efficient motors represent less than 30 percent of integral horsepower, polyphase motor sales in the United States. Market data indicate that the share of premium-efficiency motors is highest in the direct distributor channels, and lowest in motors that are sold to OEMs. With respect to motor size, premium-efficiency motor sales are lower among smaller motors (which have relatively higher efficiency differences between the lowest and highest available) and greatest among the larger motors for which the incremental cost is quite modest. Regional data is not readily available with the notable exception of New England for which a study was prepared in 1992. This study showed that new energy-efficient motors sales represented only 12 percent of motors in the 1 to 5 HP range, but over 60 percent above 60 HP.[8] Reliable information on the installed motor stock penetration level of energy-efficient motors is not available. Based on judgement and limited field surveys, experts estimate that the penetration level is probably less than 10 percent.[9]

Three distinct groups make decisions as to the efficiency of motors purchased: end-users, specifiers, and OEMs. Of the three, only the end-user stands to benefit from the energy savings resulting from higher efficiency. Specifiers and OEMs both compete on the basis of first cost, so have shown little motivation to propose, or even offer, the option of energy-efficiency motors.[10]

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[7] Easton Consultants. *Strategies to Promote Energy-Efficient Motor Systems in North America's OEM Markets.* Stamford, CT. November, 1995.

[8] Easton Consultants. *New England Motor Baseline Study.* Stamford, CT 1992.

[9] R. Neal Elliott. *Energy-Efficiency in Electric Motor Systems.* American Council for An Energy-Efficient Economy. Washington, DC. 1994

[10] N. Richard Friedman, et al. *Electric Motor System Market Transformation.* American Council for An Energy-Efficient Economy. Washington, DC. 1994.

NEMA first developed and adopted energy efficient performance values in 1989. These values were subsequently revised by NEMA and then used by the Congress as the basis for the minimum efficiency levels established in EPAct. This law establishes minimum efficiency levels for all new general-purpose electric motors[11] manufactured after October 1997.[12] The EPAct levels have been accepted as the definition of an "energy-efficient" motor by NEMA and throughout the industry.

Many manufacturers currently offer products, commonly referred to as "premium-efficiency" motors, which exceed the EPAct minimum efficiency levels by a significant amount. The difference between energy-efficient and premium-efficiency motors has been greatest among those motors that represent the greatest share of market sales, particularly 1800 rpm TEFC motors. Furthermore, it is anticipated that these motors' share of the market will continue to grow after the EPAct minimum levels go into effect, and that the efficiencies of some lower volume sizes will increase as newer designs are phased in and competition encourages further optimization of designs.

Utility Programs

A 1994 survey found 95 different utilities nation-wide offered 151 motors programs of some form, all targeted at industrial and commercial customers. Fifty-six percent of these utilities offered programs that targeted motors only, while motors were a part of a broader motors systems program for an additional 37 percent of the utilities. Motors were included as part of a broader program dealing with other end-use categories such as lighting in almost three-quarters of the programs.

Most current utility programs offer customers some kind of incentive, with a rebate amount per installed horsepower being the most frequently reported.[13] Most are currently using the EPAct levels as the threshold for incentives. Some utilities already have higher efficiency levels, but there is no consistency among the levels used by different utilities. With the EPAct levels going into effect in 1997, all utilities that continue to provide some form of incentive will need to move to some higher level.

It has been widely assumed that most of these utilities are moving away from rebate programs as utilities restructure. In the process of developing this program, the CEE Motors Committee found that many utilities plan to continue some form of motors incentive program, though perhaps with some shift from rebates to financing. Of those utilities no longer offering incentives, most remain very interested in educational/promotional or technical assistance programs for motors.

Market Barriers

A recent study of the motor marketplace identified several barriers to the adoption of energy-efficient motors.[14]

- higher first cost than a comparable standard efficiency motor,
- inadequate planning for motor replacement decisions,

[11] EPAct standards apply to NEMA design A and B, three phase, open and closed electric motors with two, four and six poles, exclusive of "definite purpose motors, special purpose motors, and those motors exempted by the secretary."
[12] House of Representatives Report 102-1018. *Energy Policy Act of 1992*, Sec. 122, pp. 41. Manufacturers have until October 1999 to comply for motors that require listing or certification by a nationally recognized testing laboratory such as UL.
[13] Robert Blevins, et al. *1994 Survey of Utility Demand-Side Programs and Services.* Electric Power Research Institute. Palo Alto, CA. 1995.
[14] Friedman, et al. 1994.

- lack of knowledge regarding actual performance and true savings from energy-efficient motors, and
- confusion as to the definitions of "high-efficiency," "premium-efficiency" and "energy-efficient" motors.

These same barriers apply to CEE premium-efficiency motors now and when EPAct minimum standards become effective. Many utilities have attempted to address the cost barrier by offering incentives for the purchase of more efficient motors. While most experts agree that the replacement of an operating standard efficiency motor is only justified in exceptional circumstances, the difference in cost between a new standard-efficiency and a new energy-efficient or premium-efficiency motor often can be recovered in less than a year. Even the incremental cost of buying a new energy-efficient or premium-efficiency motor rather than repairing a standard efficiency motor can be recovered in less than two years for most motors less than 75 HP. Incentives have proven to encourage end-users to select energy-efficient motors over repairing a standard efficiency motor. In addition, energy-efficient and premium-efficiency motors are usually more reliable than repaired motors.[15]

A number of issues should be addressed when considering the purchase of a premium-efficiency motor. For instance, on average, premium-efficiency motors have higher full load speeds which can result in increased energy consumption on centrifugal loads (e.g., fans and pumps). For belt driven equipment, the difference in speed can be compensated for by changes in pulley size.. This speed change can sometimes lead to overloading of the motor that can result in premature failure. Furthermore, high efficiency motors meet the torque requirements specified in NEMA Design B, but do not exceed the specification by as much as many older motors. As a result, a premium-efficiency motor used in an application in which torque requirements substantially exceed Design B specifications may not be able to handle the load, while an older design may be able to operate in the out-of specification condition. The appropriate applications component of this initiative **(to be developed)** addresses these and other issues.

Industry Relations

CEE recognizes that the success of this effort is largely contingent on the actions of motor manufacturers. To that end, the CEE Motor Systems Committee has sought and received extensive input from trade associations associated with the motor industry and individual manufacturers. In general, there has been support for this initiative. CEE greatly values the input and support of these groups and will continue to seek comments and advice from the industry as this program progresses.

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[15] Elliott, 1995.

About CEE:

The Consortium for Energy Efficiency is a nonprofit corporation made up of utilities, environmental and public interest groups, and government agencies. CEE is dedicated to helping private and public interests form voluntary partnerships to accelerate the development and availability of technologies that save energy, maintain customer satisfaction, and enhance environmental quality.

Appendix: Certification of Qualifying Equipment

The U.S. Department of Energy (DOE) is developing a process for certifying the nominal full-load efficiency of motors. This process, which should be finalized by the end of 1996, involved four components as proposed in Spring 1996:

- *Accreditation of test facilities* – DOE proposes that results of motor tests performed by accredited facilities would be used to determine the efficiency of motors under EPAct. The accreditation process would involve the evaluation of manufacturer and independent motor testing facilities by an independent body[16] to determine if the facilities meet internationally recognized standards for laboratory procedures and demonstrate proficiency in motor efficiency testing using either IEEE method 112b or CSA standard 390. Because of the volume of testing required, it is impractical to require testing exclusively by independent test facilities. Continued accreditation would be contingent upon rigorous record keeping, calibration of equipment, and participation in round-robin testing with other accredited laboratories.

- *Certification of motor efficiency* – Once a test facility has been accredited, it can perform tests to determine a motor's efficiency. DOE proposes that each manufacturer be required to test several samples of each basic motor design, and determine the nominal efficiency of each group of motor. If the nominal efficiency equals or exceeds the minimums required by EPAct, the test facility can then certify that the motor complies with EPAct minimums. DOE proposes to undertake independent testing to ensure the accuracy of testing performed by accredited facilities.

- *Motor labeling* – All motors certified to comply with EPAct will be labeled on the nameplate, in accordance with NEMA naming conventions, with a symbol designated by DOE indicating compliance, the efficiency as determined by testing, and the accreditation number of the certifying test facility.

- *Other reporting of efficiency* – Manufacturers are required by EPAct to report certified efficiencies for all covered motors in catalogs and other sales literature.

This process is thought to be appropriate and workable by experts from the manufacturers and the energy efficiency community.

[16] One proposal under consideration by DOE would have the National Voluntary Laboratory Accreditation Program (NVLAP) at the National Institute for Standards and Technology (NIST) serve as the accrediting agency. Test data may also be accepted based on a mutual recognition agreement with the Standards Council of Canada.

Appendix 2: CEE PREMIUM-EFFICIENCY MOTORS INITIATIVE

GUIDANCE SPECFICATION FOR LARGE (250-500 HP), LOW-VOLTAGE, GENERAL-PURPOSE MOTORS[17]

Contents

1. Introduction

This Guidance Specification represents an additional, voluntary component of CEE's Premium-Efficient Motors Initiative. It includes general recommendations as well as operating and application information for program administrators to consider when developing incentive programs for large (250-500 hp), low-voltage, general-purpose motors[18].

The recommendations reflect that large motors are more expensive, consume more energy, and have a greater potential for energy savings than smaller motors while also recognizing that changes in operating parameters have a correspondingly greater impact on energy consumption and energy savings than for their smaller counterparts. In addition, their large size coupled with the fact that large motors are often custom-ordered for specific applications increases the risks associated with prescriptive recommendations based primarily on efficiency.

The recommendations and the additional information provided in this specification are based on results of an analysis of the motors listed in the U.S. Department of Energy's MotorMaster+ database, discussions within the CEE Motors & Motor Systems Committee and motor industry input. Please note that while the operating and performance considerations were developed for large industrial motors, the same considerations apply to motors below the 250 hp level. And, as with smaller motors, not all applications benefit from the installation of NEMA Premium® motors.

2. Product Definition

[18] CEE's *Premium-Motor Specification* and the federal EPAct 1992 legislation cover motors that fall within the following parameters: 1-200 hp, low-voltage, general-purpose motors. The *NEMA Premium Specification* includes these motor categories plus 1) motors from 250-500 hp, 2) medium voltage motors and 3) special and definite purpose motors. CEE's Motors & Motor Systems Committee has been considering whether to revise the CEE Specification to include these additional NEMA Premium categories. This document addresses the first: 250-500 hp, low-voltage, general-purpose motors.

The motors covered by this Guidance Specification include: general-purpose, single-speed, polyphase, 250-500 horsepower, 2,4, and 6 pole, squirrel cage induction motors, NEMA Design A or B[19], continuous rated which meet or exceed the nominal energy efficiency levels presented in NEMA Standards Publication MG 1-2006, in Table 12-12 and as specified in Appendix A.

3. Program Guidance for Large, Low-Voltage, General-Purpose Motor Programs

The following recommendations strike a balance between the energy savings opportunities for large motors and their application-specific nature. They also reflect the benefits of consistent use of the NEMA Premium brand in the market and the opportunity to take advantage of the network of trade allies developed through CEE's *Motor Decisions Matter*[20] campaign activities.

- **Adopt a custom approach when providing incentives for 250-500 hp, low-voltage, general-purpose motors.** CEE recommends a custom approach for several reasons. Large motors, by virtue of their size, are costly to purchase and to operate. As a result, the financial consequences of promoting a premium-efficiency motor when it may not be the appropriate choice can be more significant than for smaller motors. In addition, the amount of energy consumed by large motors is more sensitive to changes in operating parameters than for small motors. Because there is wide variation in large motor applications, basing savings calculations on assumed operating parameters is more likely to lead to inaccurate projections.

  And finally, a nationally applicable baseline cannot be established from which to calculate efficiency deltas. There is no federal minimum standard for large motors. Baseline performance cannot be inferred from "typical" or "mass market" operating parameters given the large regional variation in C&I customers across North America. Finally, a baseline cannot be predicated on available product models since the 2001 introduction of the NEMA Premium brand into the market has affected the distribution of motors offered for sale in the U.S.

- **Make consideration of NEMA Premium® motors a routine part of any custom project analysis that includes large motors.** In developing custom projects, savings calculations are often based on the difference in efficiency between the old and the proposed motors, without recognition that higher efficiency products may be available. By incorporating consideration of "NEMA Premium" level efficiencies into program design, program administrators can ensure that the highest performance level that is economically feasible in each application will be identified.

  To accomplish this, program administrators are encouraged to incorporate clear terminology in relevant program descriptions; educate in-house project development and evaluation teams about motor efficiency definitions and terminology, life-cycle costing of motors and other relevant information; and extend this educational effort to others outside the organization who submit custom projects.

- **Use the "NEMA Premium®" brand name consistently throughout all communications.** It is not uncommon for motors that do *not* meet NEMA Premium efficiency levels to be labeled "premium". Therefore, CEE suggests program administrators incorporate the full "NEMA Premium®" brand name into program descriptions, promotional and educational materials, presentations and workshops for all motor sizes. Specifying "NEMA Premium", ensures that customers are, in-fact, purchasing motors that meet relevant program requirements and provide the efficiency they desire. Consistent use of the brand name may also serve to raise awareness among those who are uninformed about these products.

- **Reach out to motor vendors, distributors, sales and service centers and other trade allies to help promote (and implement) motor-related projects to customers.** Working in coordination

[19] NEMA Design designations A&B do not apply to 6 pole motors above 350 hp.

[20] The *Motor Decisions Matter* Campaign is a supplemental project of CEE sponsored by motor manufacturers, the motor sales and service industry, efficiency program administrators and others. For more information, visit http://www.motorsmatter.org.

with local motor vendors and trade allies can provide on-going, market-based implementation support for motor-related efficiency projects while also enhancing the credibility of the vendors providing those services. MDM Sponsor experience has shown, anecdotally, that customers are more receptive and likely to implement motor-related and motor-management related projects at their facilities when motor vendors, sales and service centers or other motor experts are available to provide on-going support.

- **Consider the motor's operating and application parameters when choosing the optimal motor for a given application.** A few of these are highlighted in Appendix B.

4. Efficiency Program Participation

To be a participant in this portion of the initiative, organizations should 1) include 250-500 hp, low-voltage, general-purpose motors in their program(s) and 2) inform CEE of their intent to adopt the equipment, the NEMA Premium efficiency levels (as defined in Appendix A) and/or the NEMA Premium brand name in whole or in part.

These participation requirements are consistent with the overall initiative. Any organization may participate and all motor programs, including educational/promotional, technical assistance, and incentive programs, are eligible. CEE encourages participating organizations to adopt this component because of the energy savings potential with large motors and to provide consistency of terms and definitions across organizational boundaries.

5. Current Program Approaches

A large majority of the CEE members who provide incentives for large motors (≥250 hp) do so on a custom basis[21]. Approaches include both direct and third-party programs (such as standard performance contracting). Incentives may be provided on a case-by-case basis or within the context of a larger project proposal. According to program administrators, the benefits of following a custom approach include more accurate forecasting of projected energy savings, opportunities to identify additional system savings (e.g. installation of adjustable speed drives), and reduced risk of promoting an inappropriate motor. Many administrators are comfortable with a custom approach in light of the small number of large motor applications they receive each year (often < 5% of overall applications) and the fact that large motors are often special orders and application-specific.

In developing or evaluating projects, program administrators consider the difference in efficiency between the old motor and its replacement. Most, however, do not reference or suggest a minimum efficiency for the new motor. Program administrators saw consideration of NEMA Premium motors as an opportunity to capture additional savings in these projects.

6. Current Program Approaches to Establishing a Baseline

Program administrators have shared their strategies for establishing baseline information in both custom and prescriptive approaches[22]. In custom programs, the old motor's nameplate efficiency is commonly used as the baseline for calculating projected savings. For motors without nameplate data, some programs reference the MotorMaster+ 4.0 *Table of Pre-EPAct Motors Efficiencies*. This table was developed by DOE in the early 1990s based on motors available for sale in the market at that time. The Motor Decisions Matter campaign (with the support of the campaign sponsors) refers to this table in both the *1-2-3 Approach to Motor Management* and the *Annual Estimated Savings Chart* for motors without nameplate efficiencies (see Appendix D, Table 1).

As an added consideration, some efficiency programs assume that age and/or previous repairs are likely to have reduced a motor's efficiency and discount the nameplate value accordingly. Efficiency reductions from ½% to 1 ½ % have been identified. There is some controversy in this approach, however. A recent EASA study demonstrated that motor repair can have a range of effects on efficiency depending on the specific procedures followed[23] . These effects ranged all the way from improvement to degradation. MDM's *1-2-3 Approach to Motor*

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[21] For specific information about how individual programs are addressing large motors, please refer to CEE's 2007 Motor and Drive Program Summary posted on the CEE web site, http://www.motorsmatter.org/tools/programs2007.pdf.

[22] IBID

[23] *The Effect of Repair/Rewinding on Motor Efficiency: EASA/AEMT Rewind Study*, EASA, 2003 (http://www.easa.com/indus/rwstdy1203.pdf)

Management assumes best-practice repair procedures with no resulting change in efficiency. The MotorMaster+ 4.0 software inserts a ½% reduction in efficiency for motors that have been repaired which the user can override.

Another source of data that may be considered when developing a baseline is NEMA's Energy-Efficient (EE) specification[24] . The efficiency values listed in this table are equivalent to those specified in the EPAct 1992 legislation for motors common to both specifications. Unlike EPAct 1992, however, the NEMA EE includes motors up to and including 500 hp (see Appendix D, Table 2).

7. Potential Energy Savings for Large Motors

According to the Department of Energy's *1998 United States Industrial Electric Motor Systems Market Opportunities Assessment*[25]*,* industrial motor systems account for approximately twenty-three per cent of all electricity consumed in the United States and that consumption could be reduced by up to 18 per cent through the use of currently available products and practices. The study goes on to state that while large industrial motors, i.e. those over 200 horsepower, represent a small percentage of the overall industrial motor population, they represent a significant amount of the overall energy consumed by industrial motor systems. The study goes on to estimate potential energy savings of approximately *2.6 billion kWh annually* through installation of energy efficient motors in the 250-500 hp size range. Additional market data includes the following:

- Motors over 200 horsepower account for only one percent of the motors in the entire manufacturing inventory, but use 45 percent of the energy use. By way of contrast, motors in the 1-5 hp range account for 59 percent of the inventory but account for only 5 percent of the energy use.
- Approximately 70% of motors which are >200 horsepower, fall into the 250-500 hp size range.
- Over 80% of the motors in this size range are older (pre-1992) models.
- Average annual motor system operating hours exceed 6,100 hours per year.

While the DOE study was published in 1998, it is sited here because it remains the most comprehensive information available for estimating the magnitude of potential energy savings. In addition, recent studies by individual CEE members as well as program experience assessing motor opportunities at customer facilities have confirmed that the opportunities for energy savings through the use of premium efficient motors and motor system optimization remains significant in those regions. The data is not intended to approximate actual savings and program administrators are encouraged to consider the data's relevance in their individual territories.

8. Potential Market Implications

There is government support for NEMA Premium general-purpose motors up to 500 hp. EPAct 2005 and the ensuing FEMP ruling requires federal agencies to purchase motors, which meet the NEMA Premium efficiency levels for all federal motor purchases up to 500 hp. For more information, please visit http://www.eere.energy.gov/.

Program administrators can build on federal support by participating in this component of the initiative and help draw attention to the possible energy savings from the installation of large, low-voltage NEMA Premium motors in appropriate applications. Consistent support by programs across North America can help to condition the market for energy savings and increase customer confidence in the savings potential of these products.

Using the words "NEMA Premium" to specify premium-efficient motors can serve to clear up misperceptions in the market. Customers who specify "energy efficient" motors often assume they are ordering the highest efficiency motors available[26]. However, because the EPAct 1992 legislation defines "energy efficient" as motors meeting the minimum federal standard, and because there are products labeled "Premium" which do not meet "NEMA Premium" efficiency levels, customers may not realize there are higher efficiency motors available. By incorporating the full "NEMA Premium®" brand name, participating programs can help to alleviate this confusion

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[24] As defined by NEMA MG-1 2003 Table 12-11

[25] *United States Industrial Motor Systems Market Opportunities Assessment*, prepared by Xenergy for the U.S. DOE's Office of Industrial Technologies and Oak Ridge National Laboratory, 1998

[26] Customer confusion regarding the term "energy-efficient motors" has been reported by program administrators, motor manufacturers, and motor sales and service center representatives.

and simplify promotion of NEMA Premium motors by all stakeholders in the market. Consistent support may also condition end-use customers to equate the NEMA Premium brand name with energy savings and enhance the level of manufacturer attention to these higher efficiency products.

Participants may also enhance the impact of their programs by joining manufacturers, vendors and service providers to promote a single specification and recognizable brand to their customers. Consistency among these diverse stakeholder groups coupled with efficiency programs' public recognition of the value of NEMA Premium for large motors creates a clear and credible signal to the market. The *Motor Decisions Matter* campaign sponsors, including representatives from each of these stakeholder groups, have developed a consistent message plus educational materials and resources for delivering that message to the market[27]. Increasing the number of participating organizations delivering this consistent message may further condition the market about energy savings potential in appropriate large motor applications.

[27] These resources are freely available for use on the MDM web site, www.motorsmatter.org or by contacting CEE Industrial Program Staff.

APPENDIX A

NEMA PREMIUM® EFFICIENCY SPECIFICATIONS FOR 250-500 HP MOTORS[28]

(Terms of Usage follow)

EFFECTIVE DATE: TBD

Table 1: Nominal Full Load Efficiencies for Industrial Three-Phase Motors 250-500 hp ODP, NEMA Design A and B, Low-voltage, General Purpose, 1200, 1800 and 3600 RPM

Open Drip-Proof (ODP)			
	1200 RPMs	1800 RPMs	3600 RPMs
HP	NEMA Premium Efficient	NEMA Premium Efficient	NEMA Premium Efficient
250	95.4	95.8	95.0
300	95.4	95.8	95.4
350	95.4	95.8	95.4
400	95.8	95.8	95.8
450	96.2	96.2	95.8
500	96.2	96.2	95.8

Table 2: Nominal Full Load Efficiencies for Industrial Three-Phase Motors 250-500 hp TEFC, NEMA Design A and B, Low-voltage, General Purpose, 1200, 1800 and 3600 RPM

Totally Enclosed Fan-Cooled (TEFC)			
	1200 RPMs	1800 RPMs	3600 RPMs
HP	NEMA Premium Efficient	NEMA Premium Efficient	NEMA Premium Efficient
250	95.8	96.2	95.8
300	95.8	96.2	95.8
350	95.8	96.2	95.8
400	95.8	96.2	95.8
450	95.8	96.2	95.8
500	95.8	96.2	95.8

See next page for Terms of Usage.

[28] EPAct 2005 requires all federal motor purchases to meet FEMP-designated performance requirements. FEMP has adopted requirements that are equivalent to these NEMA Premium specification levels.

CEE PREMIUM-EFFICIENCY MOTORS INITIATIVE
NEMA PREMIUM®EFFICIENCY SPECIFICATIONS FOR 250-500 HP MOTORS

Terms of Usage

APPENDIX B

OPERATING PARAMETERS

The motor's specific application is an important consideration when calculating projected savings with NEMA Premium motors. This is especially true for large motors where variations in operating parameters are more likely to significantly impact energy consumption. Program administrators may want to consider setting guidelines performance and/or eligibility requirements for one or more operating parameters including but not limited to:

Motor Sizing: Many motors are oversized for their applications, running far below their rated loads[29]. Given that motor efficiency may drop off sharply below 40 percent of rated load[30], motors that are severely under-loaded often operate far below their nameplate efficiency. For these motors, downsizing or installing an ASD may reduce energy consumption in some applications.

It is important to verify the motor's full range of operating parameters with the customer before recommending these options. In addition, referencing individual motor efficiency curves may provide more accurate savings projections at various loads.

Duty Cycle (and the use of Adjustable Speed Drives): Some motors experience significant variations in load. For these motors, particularly in centrifugal applications (like pumps and fans), program administrators should be aware of the opportunity to save energy through the use of adjustable speed drives (ASDs). Many NEMA Premium motors are inverter compatible, i.e. built to withstand transient voltage surges, which simplifies connection to ASDs. Application of ASDs on larger horsepower motors may require additional specifications such as "inverter duty", e.g. NEMA MG 1-2006, Part 31, insulated bearings, shaft grounding, etc.

Hours of Operation: The more hours a motor operates, the greater the opportunity for energy savings through efficiency. This is especially true for large motors as they require proportionally more power to operate than smaller motors. According to the DOE Study sited previously[31], larger motors generally experience long operating hours, often two to three shifts per day[32]. A number of efficiency programs offering incentives for large motors specify a minimum number of hours in their program criteria.

Motor Connections: How the motor is connected to the line is also important. Motor design and selection must include whether the motor experiences an across the line, part winding or soft start. The use of ASDs and inverter duty motors are included in this consideration.

Voltage Unbalance: occurs when there are unequal voltages on the lines to a polyphase motor resulting in a dramatic increase in motor losses and heat generation. Both decrease the efficiency of the motor and shorten its life[33]. Voltage unbalance may also reduce motor torque. The *Energy-Efficient Motor Systems: A Handbook on Technology, Program and Policy Opportunities*[34] provides a brief introduction to this topic including formulas for calculating voltage unbalance and possible solutions.

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[29] The Motor Resource Center reports that 30% of the motors tested in a recent study were operating at less than 50% load. The full report, "*Achieving More with Less: Efficiency and Economics of Motor Decision Tools*" is available on their Web site, www.motorresourcecenter.org/docs/motor_decision_tools_comprehensive_final_report.pdf.

[30] The MRC study also found that, as load was reduced, the efficiency curves for NEMA Premium motors maintained a generally flatter shape when compared to efficiency curves of non-NEMA Premium motors.

[31] *United States Industrial Motor Systems Market Opportunities Assessment*, prepared by Xenergy for the U.S. DOE's Office of Industrial Technologies and Oak Ridge National Laboratory, 1998

[32] Calculated as follows: (8 hours/shift) x (3 shifts/day) x (5 days/week) x (50 weeks/year) = 6000 hours/year

[33] Efficient Motors: Selection Application Considerations, Consortium for Energy Efficiency, Boston MA 1999

[34] Nadel, Steven, et al, "*Energy-Efficient Motor Systems: A Handbook on Technology, Program and Policy Opportunities"*, ACEEE Washington DC, 2002.

9. Design Factors

Because industrial processes include a wide range of applications, manufacturers have designed products to optimize a variety of performance characteristics. In-rush current, torque and power factor are a few examples. Efficiency may be independent of, in direct relationship to or inversely proportional to these other characteristics. Industrial process designers, engineers and managers must consider which characteristics need to be optimized for their specific application and choose the motor accordingly. It is important for efficiency program administrators to recognize the possibility that efficiency may or may not be the primary consideration in all applications.

Below are definitions of a few common design characteristics; their relationship to efficiency is provided where possible. This list is provided to raise issues that program administrators might want to evaluate and consider; it is not intended as a check-list of items to include in custom project analyses. Development of appropriate engineering analysis and guidelines, performance and/or eligibility requirements are left to the discretion of individual program administrators.

For more information on any of these topics, please refer to NEMA's -2006 1 Standards Publication, or consult your local motor vendors. You may also contact any of the motor manufacturer or EASA sponsors of the Motor Decisions Matter Campaign (contact mdminfo@cee1.org for more details).

While program administrators are encouraged to consider all the factors described below, two are of particular importance: slip and current. Attention to a motor's slip rate is important to ensure that energy savings are achievable. Instantaneous peak inrush current is an important consideration to avoid nuisance tripping during start up. These factors are described in more detail below.

Motor System Optimization: Optimizing industrial processes may offer additional significant savings opportunities. When considering motor purchases and application parameters, program administrators are encouraged to also consider system design changes that might reduce the total amount of horsepower required.

Current (in amperes or percent of rated current): the amount of current the motor draws at a particular time or under particular operating conditions. There are many points of defined current which can be important considerations in a given application.

NEMA recognizes and describes two components of starting current: instantaneous peak inrush current (the momentary transient current that occurs within ½ cycle after contact closure and which may range from 1.8 to 2.8 times the locked-rotor current at ambient temperature) and locked-rotor current (the steady-state current taken from the line, with the rotor locked and with rated voltage applied). These are important as installation of NEMA Premium motors may increase the incidence of nuisance tripping if either of these values is higher than the original motor.

ATTENTION: Higher efficiency motors generally have a slightly higher locked-rotor current than standard-efficiency motors. Therefore, replacing an older motor with a NEMA Premium motor may cause nuisance tripping in some applications. This is seldom a problem for Design B motors for which NEMA defines a maximum allowable locked-rotor current. It is more common with Design A motors for which NEMA does not define a maximum allowable locked-rotor current.

For more information including suggested remedies, please refer to U.S. Department of Energy Tip Sheet, "Avoid Nuisance Tripping with Premium Efficiency Motors," available on the EERE website, http://www1.eere.energy.gov/industry/bestpractices/tip_sheets_motors.html

Design: NEMA design letters (A through D) are an indication of the shape of the torque-speed curve. The designation also defines a number of electrical criteria including but not limited to: full-voltage starting and locked-rotor torque, pull-up torque, breakdown torque, locked-rotor current, and slip. All performance testing is performed in accordance with IEEE Std 112 or CSA 390.

NEMA Premium motors must be *Design A* or *Design B.*

- Design B motors are the dominant type on the market and are used for most applications including fans, pumps, some compressors, and many other types of machinery.
- Design A motors are similar to Design B motors except that the maximum torque and starting currents may be higher. A common application for Design A motors is injection molding machines.

Efficiency: the ratio (in percent) of mechanical power output to the electrical power input.

NEMA's MG 1-2006 defines both "energy-efficient" and "NEMA Premium-efficient" performance levels for open and closed enclosures for each motor size between 1 and 500 hp. The "energy-efficient" performance levels are the same as those specified in EPAct 1992 (the federally mandated minimum efficiency) where the two specifications overlap. The term "energy efficient" is sometimes misinterpreted in the market as "premium-efficient".

Full Load Amps: the amount of current the motor can be expected to draw under full-load (torque) conditions when operating at the rated voltage. This value is printed on the nameplate.

Power factor (in percent): the ratio between the real power (measured in W or kW) and the apparent power (measured in VA or kVA). Power factor, like many other motor performance characteristics, is related to core length, material properties, and air gap among other things. It is generally higher for larger motors than for smaller ones. It is not a design criterion for NEMA Premium motors. The use of ASDs may affect power factor - older ASD technologies may negatively impact a motor's power factor while newer Pulse Width Modulated (PWM) ASDs may improve it. Capacitors are often used to correct for low power factor[35].

Slip (in percent or rpm): the difference between the motor's synchronous (design) speed and its actual speed. Since power consumption is related to the cube of the speed, in centrifugal applications like fans and centrifugal pumps, slip becomes an important consideration. System control circuits may lessen this effect. The NEMA MG 1-2006 tolerance for slip is 20%, i.e. a motor rated 1750 rpm would have 50rpm slip, plus or minus 10 rpm (20% of 50).

ATTENTION: To avoid unintentional increases in power consumption when replacing a motor, program administrators should consider the application to assess whether changes in the slip rate will be of concern, e.g. centrifugal loads. The effect of the system's control circuits should also be considered.

Service Factor specifies the capacity of the motor to withstand prolonged overload conditions. For example, if the service factor is 1.15, the motor can work at 1.15 times its rated horsepower satisfactorily, although the insulation life will be reduced. In general, it is not good practice to operate a motor for extended periods in the service factor area; efficiency may be lower and additional heating can lessen motor life.

Temperature Rise the amount of temperature rise that can be expected within the windings of the motor when going from non-operating (ambient condition) to full load and continuous operation.

[35] In addition to power factor, ASDs may also affect line power quality. This impact can be corrected with filter circuits. Please refer to IEEE 519, *Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems*, for more information.

Torque (in pound-feet, pound inches, ounce-feet, or percent of full-load torque): the twisting force exerted by the motor shaft on the load. There are many defined terms related to torque such as pull-out torque, breakdown torque and pull-up torque. Two commonly used definitions are:

> Locked-Rotor Torque (also called Starting Torque): the amount of torque the motor produces when energized at full-rated voltage with the shaft locked in place. It is the amount of torque available when the motor is energized to break the load away (start it moving) and begin accelerating it up to speed.
>
> Full-Load Torque the rated continuous torque that the motor can produce without overheating within its time rating.

APPENDIX C

RESULTS OF CEE'S ANALYSIS OF THE MOTORS CATALOGUED IN DOE'S MOTORMASTER+ 4.0 SOFTWARE

Early in the consideration process (December 2004), the Motor & Motor Systems Committee raised several basic questions regarding the performance, availability and incremental cost of 250-500 hp motors. Specifically, the questions were:

1. Are the energy efficiency gains for 250-500 hp motors (non-NEMA Premium to NEMA Premium) equivalent to those seen in smaller motors?
2. Is there a significant difference in the amount of slip exhibited by 250-500 hp motors than by smaller motors?
3. How does the incremental cost difference between the NEMA Premium and non-NEMA Premium models compare?
4. Are there sufficient products available?

To answer these questions, CEE contracted with Washington State University to provide an analysis of the motors listed in the MotorMaster+ 4.0 database. The results of that analysis appear below. For more information about the data, analysis plan or the results, please contact Ilene Mason, imason@cee1.org.

Question 1: Motor Efficiency

To assess the significance of the efficiency improvements available through the use of NEMA Premium motors, we compared mean nominal efficiencies for motors 100-200 hp with motors 250-500 hp for three motor classes (all motors; motors which meet or exceed the NEMA Premium efficiency; and motors that fall below the NEMA Premium value). The differences were then quantified based on the standard deviation which had been calculated for that category and compared to the nominal efficiency defined by the NEMA Premium specification.

This was a unique approach to assessing efficiency. Specifically, we assumed that the "normal" mix of products one would expect to find in the market had been skewed upward by the introduction of the NEMA Premium brand in 2001. Therefore the number of NEMA Premium models available could not be used to approximate their market share. This shift in product mix, combined with the mandated minimum performance criteria for 1-200 hp motors (due to the enactment of the 1992 EPAct legislation), rendered CEE's normal process for establishing "premium performance" levels unsuitable. Therefore, in this analysis, we compared the mean efficiency deltas for categories of motors under consideration to categories where CEE had defined performance levels prior to the market adoption of EPAct and NEMA Premium. During the discussions, there was general agreement that this methodology for comparing the efficiency levels of motors above and below 200 hp was logical and reasonable. For more information, please contact Ilene Mason, imason@cee1.org.

Results:

Conventional wisdom was that large motors are generally more efficient than smaller ones. Therefore, the efficiency improvement for purchasing a NEMA Premium motor would be smaller. Our analysis did not prove this assumption. Rather, the results showed a larger percentage of motor categories where the mean efficiency fell further below the NEMA Premium nominal value for motors 250-500 hp than for motors 100-200 hp.

Specifically, our analysis showed a larger percentage of size/speed/enclosure categories where the mean efficiency fell more than one standard deviation away from the NEMA Premium specification nominal value for large motors (250-500 hp) than for smaller ones (100-200 hp) (see Table 1) . Another unexpected result was that there were a number of categories where the category mean fell more than two standard deviations from the NEMA nominal value for these large motors. (Obviously, there were no categories of motors <200 which fell this far from the nominal due to EPAct 1992's mandated minimum efficiency levels.)

Table 1: Distribution of Mean Efficiency Relative to NEMA Premium Nominal Values

Motor Size	# Categories	# Motors	Percentage of Categories that are within 1 'Ω below nominal	Percentage of Categories that are between 1 and 2 'Ω's below nominal	Percentage of Categories that are more than 2 'Ω's below nominal
ALL Motors: Closed					
100-200 hp	12	607	50%	50%	0%
250-500 hp	18	332	56%	33%	11%
ALL Motors: Open					
100-200 hp	12	374	83%	17%	0%
250-500 hp	18	185	80%	13%	7%
Non-NEMA Premium Motors Only: Closed					
100-200 hp	12	406	17%	83%	0%
250-500 hp	18	229	0%	80%	20%
Non-NEMA Premium Motors Only: Open					
100-200 hp	12	184	50%	50%	0%
250-500 hp	18	111	7%	93%	0%

Question 2: Motor Slip

Since power consumption is related to the cube of the speed, slip becomes an important consideration in centrifugal applications like fans and centrifugal pumps. Replacing a motor with a more efficient model but which has less slip may actually increase the amount of power consumed and so is an important consideration. We anticipated that large motors would generally exhibit less slip than smaller ones.

Results: No firm conclusions could be drawn from this analysis. A brief, subsequent look at individual motor data in two categories (by WSU) showed significant variation in the amount of slip exhibited by motors within a given category. The data suggests that for slip-sensitive applications (like pumps and fans), the application needs to be considered on an individual basis, recognizing both motor and system control impacts.

Question 3: Motor Costs

Definition: This analysis looked at the difference in mean cost between NEMA Premium and non-NEMA Premium motors for each of the sixty categories based on manufacturer reported prices contained in the MotorMaster+ database.

Results: The data showed that the difference in list price between NEMA Premium and non-NEMA Premium motors was consistently greater for motors 250-500 hp than for motors 100-200 hp. It is important to keep in mind that this analysis looked at reported pricing. Actual motor costs are likely to vary by region, purchase quantity, the buyer/seller relationship, existing contracts, or other relevant factors.

Question 4: Motor Availability

There are a reasonable number of NEMA Premium products available in most categories. Specifically, products were available in 54 of the 60 categories we analyzed; 45 of the 60 categories had ten or more motor models listed. Three categories had less than three motors (n<3). NEMA posts a table listing the participating manufacturers who provide products in various categories on their web site, http://www.nema.org/gov/energy/efficiency/premium/.

Based on manufacturer information, additional products are also available. Our analysis was based on motors reported in the MotorMaster+ 4.0 database and includes only "standard" or "off-the-shelf" models. According to the manufacturers, more configurations are available but, since they are often considered specialty items, are not included in the MotorMaster+ listing. Specialty in this case may refer to special testing, specific performance characteristics, or special mounting configurations.

APPENDIX D: TABLE 1: COMPARING EFFICIENCY SPECIFICATIONS

MotorMaster+ 4.0 PreEpact Default Values : NEMA Premium Specification MG 1-2006 Table 12-12

Note: There is a seeming discrepancy between this Appendix and the conclusions drawn regarding efficiency in Appendix A. This discrepancy is due to the difference in the data sources. This table provides information about performance specifications while the Appendix A data provides information regarding the models available in the market today.

Open Drip-Proof (ODP)						
	1200 RPMs		1800 RPMs		3600 RPMs	
HP	MM+ 4.0 Pre- 1992 Defaults[36]	NEMA PREMIUM Efficient[37]	MM+ 4.0 Pre- 1992 Defaults[10]	NEMA PREMIUM Efficient[11]	MM+ 4.0 Pre- 1992 Defaults[10]	NEMA PREMIUM Efficient[11]
1	74.5	**82.5**	77.6	**85.5**	76.2	**77**
1.5	77.6	**86.5**	79.3	**86.5**	77.3	**84**
2	79.9	**87.5**	80.5	**86.5**	79.6	**85.5**
3	81.7	**88.5**	82.4	**89.5**	79.1	**85.5**
5	83.6	**89.5**	83.8	**89.5**	82.6	**86.5**
7.5	85.5	**90.2**	85.2	**91.0**	82.9	**88.5**
10	87.4	**91.7**	86.1	**91.7**	85.0	**89.5**
15	87.0	**91.7**	87.8	**93.0**	86.6	**90.2**
20	87.7	**92.4**	88.3	**93.0**	88.1	**91.0**
25	89.0	**93.0**	88.9	**93.6**	88.5	**91.7**
30	89.5	**93.6**	88.9	**94.1**	87.7	**91.7**
40	89.4	**94.1**	90.0	**94.1**	88.6	**92.4**
50	89.7	**94.1**	90.7	**94.5**	89.1	**93.0**
60	90.8	**94.5**	91.3	**95.0**	90.4	**93.6**
75	91.5	**94.5**	91.9	**95.0**	90.4	**93.6**
100	92.2	**95.0**	92.1	**95.4**	90.5	**93.6**
125	92.0	**95.0**	92.2	**95.4**	91.2	**94.1**
150	92.6	**95.4**	92.8	**95.8**	91.7	**94.1**
200	92.9	**95.4**	93.0	**95.8**	91.5	**95.0**
250	94.1	**95.4**	94.4	**95.8**	93.0	**95.0**
300	94.4	**95.4**	94.6	**95.8**	93.9	**95.4**
350	94.5	**95.4**	94.1	**95.8**	94.2	**95.4**
400	95.4	**95.8**	94.7	**95.8**	94.4	**95.8**
450	95.4	**96.2**	95.0	**96.2**	94.6	**95.8**
500	95.4	**96.2**	95.0	**96.2**	94.6	**95.8**

Totally Enclosed Fan-Cooled (TEFC)						
	1200 RPMs		1800 RPMs		3600 RPMs	
HP	MM+ 4.0 Pre- 1992 Defaults[10]	NEMA PREMIUM Efficient[11]	MM+ 4.0 Pre- 1992 Defaults[10]	NEMA PREMIUM Efficient[11]	MM+ 4.0 Pre- 1992 Defaults[10]	NEMA PREMIUM Efficient[11]
1	73.4	**82.5**	76.7	**85.5**	73.0	**77.0**
1.5	77.9	**87.5**	79.1	**86.5**	75.2	**84.0**
2	78.3	**88.5**	80.8	**86.5**	78.9	**85.5**
3	80.4	**89.5**	81.5	**89.5**	79.6	**86.5**
5	83.1	**89.5**	83.3	**89.5**	82.4	**88.5**
7.5	84.4	**91.0**	85.5	**91.7**	82.6	**89.5**
10	85.0	**91.0**	85.7	**91.7**	85.0	**90.2**
15	87.0	**91.7**	86.6	**92.4**	85.7	**91.0**
20	87.7	**91.7**	88.5	**93.0**	86.6	**91.0**
25	88.9	**93.0**	89.3	**93.6**	87.5	**91.7**
30	89.6	**93.0**	89.6	**93.6**	87.7	**91.7**
40	89.9	**94.1**	90.2	**94.1**	88.5	**92.4**
50	90.6	**94.1**	91.3	**94.5**	89.0	**93.0**
60	90.8	**94.5**	91.8	**95.0**	89.4	**93.6**
75	91.6	**94.5**	91.7	**95.4**	90.6	**93.6**
100	91.4	**95.0**	92.3	**95.4**	90.9	**94.1**
125	92.1	**95.0**	92.2	**95.4**	90.9	**95.0**
150	93.1	**95.8**	93.0	**95.8**	91.5	**95.0**
200	92.6	**95.8**	93.5	**96.2**	92.7	**95.4**
250	94.4	**95.8**	94.2	**96.2**	94.7	**95.8**
300	94.4	**95.8**	94.4	**96.2**	94.7	**95.8**
350	94.3	**95.8**	94.6	**96.2**	94.7	**95.8**
400	95.0	**95.8**	94.8	**96.2**	94.8	**95.8**
450	95.0	**95.8**	94.9	**96.2**	94.5	**95.8**
500	95.0	**95.8**	94.9	**96.2**	94.5	**95.8**

[36] These values are taken from DOE's MotorMaster+ database (circa 1992) for standard motors referenced to the NEMA 6-B. Source: Personal communication with Gilbert McCoy, P.E. Energy Systems Engineer, OIT Clearinghouse, August 19, 2003. They are used as default values for pre-EPAct 1992 motors by MotorMaster+ 4.0 and MDM's *1-2-3 Approach to Motor Management*.

[37] This is NEMA's "Premium-Efficient" specification level (MG1-1998 (Rev 3 2002) Table 12-12). It is equivalent to CEE's Premium Motor Specification for motors common to both. It also meets the Federal Energy Management Program (FEMP) designated performance requirement for federal motor purchases.

APPENDIX D: TABLE 2: COMPARING EFFICIENCY SPECIFICATIONS

NEMA Energy Efficient Spec MG 1-2006 : Table 12-11 : NEMA Premium Spec MG 1-2006 Table 12-12

Note: There is a seeming discrepancy between this Appendix and the conclusions drawn regarding efficiency in Appendix A. This discrepancy is due to the difference in the data sources. This table provides information about performance specifications while the Appendix A data provides information regarding the models available in the market today.

Open Drip-Proof (ODP)							Totally Enclosed Fan-Cooled (TEFC)						
	1200 RPMs		1800 RPMs		3600 RPMs			1200 RPMs		1800 RPMs		3600 RPMs	
HP	NEMA EE : Energy Efficient[38]	NEMA PREMIUM Efficient[39]	NEMA EE: Energy Efficient[12]	NEMA PREMIUM Efficient[13]	NEMA EE: Energy Efficient[12]	NEMA PREMIUM Efficient[13]	HP	NEMA EE: Energy Efficient[12]	NEMA PREMIUM Efficient[13]	NEMA EE: Energy Efficient[12]	NEMA PREMIUM Efficient[13]	NEMA EE: Energy Efficient[12]	NEMA PREMIUM Efficient[13]
1	80.0	**82.5**	82.5	**85.5**	…	**77.0**	***1***	80.0	**82.5**	82.5	**85.5**	75.5	**77.0**
1.5	84.0	**86.5**	84.0	**86.5**	82.5	**84.0**	***1.5***	85.5	**87.5**	84.0	**86.5**	82.5	**84.0**
2	85.5	**87.5**	84.0	**86.5**	84.0	**85.5**	***2***	86.5	**88.5**	84.0	**86.5**	84.0	**85.5**
3	86.5	**88.5**	86.5	**89.5**	84.0	**85.5**	***3***	87.5	**89.5**	87.5	**89.5**	85.5	**86.5**
5	87.5	**89.5**	87.5	**89.5**	85.5	**86.5**	***5***	87.5	**89.5**	87.5	**89.5**	87.5	**88.5**
7.5	88.5	**90.2**	88.5	**91.0**	87.5	**88.5**	***7.5***	89.5	**91.0**	89.5	**91.7**	88.5	**89.5**
10	90.2	**91.7**	89.5	**91.7**	88.5	**89.5**	***10***	89.5	**91.0**	89.5	**91.7**	89.5	**90.2**
15	90.2	**91.7**	91.0	**93.0**	89.5	**90.2**	***15***	90.2	**91.7**	91.0	**92.4**	90.2	**91.0**
20	91.0	**92.4**	91.0	**93.0**	90.2	**91.0**	***20***	90.2	**91.7**	91.0	**93.0**	90.2	**91.0**
25	91.7	**93.0**	91.7	**93.6**	91.0	**91.7**	***25***	91.7	**93.0**	92.4	**93.6**	91.0	**91.7**
30	92.4	**93.6**	92.4	**94.1**	91.0	**91.7**	***30***	91.7	**93.0**	92.4	**93.6**	91.0	**91.7**
40	93.0	**94.1**	93.0	**94.1**	91.7	**92.4**	***40***	93.0	**94.1**	93.0	**94.1**	91.7	**92.4**
50	93.0	**94.1**	93.0	**94.5**	92.4	**93.0**	***50***	93.0	**94.1**	93.0	**94.5**	92.4	**93.0**
60	93.6	**94.5**	93.6	**95.0**	93.0	**93.6**	***60***	93.6	**94.5**	93.6	**95.0**	93.0	**93.6**
75	93.6	**94.5**	94.1	**95.0**	93.0	**93.6**	***75***	93.6	**94.5**	94.1	**95.4**	93.0	**93.6**
100	94.1	**95.0**	94.1	**95.4**	93.0	**93.6**	***100***	94.1	**95.0**	94.5	**95.4**	93.6	**94.1**
125	94.1	**95.0**	94.5	**95.4**	93.6	**94.1**	***125***	94.1	**95.0**	94.5	**95.4**	94.5	**95.0**
150	94.5	**95.4**	95.0	**95.8**	93.6	**94.1**	***150***	95.0	**95.8**	95.0	**95.8**	94.5	**95.0**
200	94.5	**95.4**	95.0	**95.8**	94.5	**95.0**	***200***	95.0	**95.8**	95.0	**96.2**	95.0	**95.4**
250	95.4	**95.4**	95.4	**95.8**	94.5	**95.0**	***250***	95.0	**95.8**	95.0	**96.2**	95.4	**95.8**
300	95.4	**95.4**	95.4	**95.8**	95.0	**95.4**	***300***	95.0	**95.8**	95.4	**96.2**	95.4	**95.8**
350	95.4	**95.4**	95.4	**95.8**	95.0	**95.4**	***350***	95.0	**95.8**	95.4	**96.2**	95.4	**95.8**
400	…	**95.8**	95.4	**95.8**	95.4	**95.8**	***400***	…	**95.8**	95.4	**96.2**	95.4	**95.8**
450	…	**96.2**	95.8	**96.2**	95.8	**95.8**	***450***	…	**95.8**	95.4	**96.2**	95.4	**95.8**
500	…	**96.2**	95.8	**96.2**	95.8	**95.8**	***500***	…	**95.8**	95.8	**96.2**	95.4	**95.8**

[38] This is NEMA's "Energy-Efficient" designation (MG1-1998 (Rev 3 2002) Table 12-11). It is equivalent to EPACT 1992 for motors common to both performance specifications.

[39] This is NEMA's "Premium-Efficient" specification level (MG1-1998 (Rev 3 2002) Table 12-12). It is equivalent to CEE's Premium Motor Specification for motors common to both. It is also equivalent to FEMP- designated performance requirement for federal motor purchases.

APPENDIX E

HISTORICAL BACKGROUND

EPAct 1992 and CEE: In 1992, the federal government mandated a minimum efficiency level for all three-phase, squirrel cage, low-voltage, general-purpose motors in the 1-200 horsepower size range sold in the U.S. The legislation is commonly referred to as EPAct 1992. Recognizing the opportunity to promote motors with higher efficiency levels than EPACT 1992 required, CEE developed a premium energy efficiency specification for the same classes of motors. The efficiency levels specified were generally two NEMA efficiency bands (Table 12-10, NEMA MG 1-2006) above those required by EPACT. This voluntary specification covered the following motors:

speed	2, 4, and 6 pole
size	1-200 hp
design	NEMA A and B
enclosure type	ODP and TEFC
voltage	low voltage

NEMA and CEE: In 2001, there remained a great deal of confusion in the marketplace as to what constituted the most efficient motors currently available in the market. NEMA, CEE, and other stakeholders responded by developing and adopting the NEMA Premium specification in 2001. This voluntary specification was adapted from the CEE criteria and serves as the benchmark for premium energy efficient motors. NEMA Premium also denotes a brand name for motors which meet this specification. The NEMA Premium Specification (Tables 12-12 and 12-13 of MG 1, Revision 3) covers a wider range of motors than the EPACT 1992 and CEE Specifications:

speed	2, 4, and 6 pole
size	1-500 hp
design	NEMA A and B
enclosure type	open and enclosed
voltage	low and medium voltage
class	general, definite, and special purpose

CEE Today: In 2005, CEE's Motors & Motor Systems Committee members began considering whether to revise the CEE Premium Motor Specification to more closely align with the NEMA Premium Specification. As a first step in this process, the committee considered the category of low-voltage motors from 250-500 hp and in 2006 recommended including those motors in the CEE Specification. Given the application-specific nature of these large motors, however, and the possible large-scale consequences of incorrectly promoting a NEMA Premium motor when it may not be the appropriate choice, the group also supported developing a guidance document that would highlight the potential energy savings as well as provide general performance and application information that would be helpful to those interested in providing incentives for these motors.

EPAct 2005: Section 104 of the Energy Policy Act of 2005 requires federal agencies to procure only Energy Star-qualified or FEMP- designated products except where such products will not be cost-effective over their life or no product is reasonably available.

The Federal Energy Management Program (FEMP) has designated performance requirements for general purpose motors of 1-500 horsepower (low voltage) and 250-500 horsepower (medium voltage). FEMP's performance requirements match NEMA Premium performance levels and also match CEE's performance levels for motors of 1-200 horsepower (low voltage).